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IBHVG2: Mortar Simulation With Interior Propellant Canister

by Ronald D. Anderson

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14. ABSTRACT

A method has been implemented for the Interior Ballistics of High Velocity Guns, Version 2 (IBHVG2) simulation program to model mortar systems, including an enclosed high-pressure igniter canister. The application allows initial pressurization of the canister until interior pressure reaches a force high enough to rupture a burst diaphragm. Combustion gases are then released to the larger (main) chamber to accelerate the projectile or to ignite additional propellant for the ballistic cycle. The canister may release its contents through a burst disk (directly and completely into the main chamber) or through vent holes (controlling rate of exhaust). Gas and particle flow through vents is regulated via discharge coefficients, which the modeler may use to closely approximate experimental mortar data.

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Contents

List of Figures

Acknowledgments

The original effort to add these mortar options was spearheaded by Mr. Frederick Robbins, formerly of U.S. Army Research Laboratory (ARL), who inserted the IBHVG2 links necessary to use the canister as an independent volume and to cause gas to exhaust from the canister in burst mode or permeable flow. This final version rests mightily upon his work.

Mr. Albert Horst of ARL contributed valuable discussions as the project developed, and his guidance helped shape the final report.

1. Introduction

The propelling charge in a mortar round is usually contained in a closed canister, or at least includes an igniter propellant in a closed container. Some rounds may also have exterior propellants added before the round is used. Propellants in the closed canister ignite and burn in a volume smaller (and at higher pressure) than the main chamber volume, then vent combustion products into the larger chamber for expansion, exterior propellant ignition, and projectile acceleration.

Propellant burning in a canister releases hot gases and fragments of burning propellant into the larger chamber through a burst vent or a series of vent pores from the smaller compartment. The main (large) chamber volume consists of the region from the rear face of the tube forward to the "sealing point" between projectile and tube wall and may be many times larger than the canister. The high-pressure ignition and combustion process in the canister is much more reliable than ignition-combustion of a small-mass propellant in a large-volume chamber.

The aforementioned processes (small-volume propellant [or igniter] chamber with a burst vent or with vent pores) have been added to the Interior Ballistics of High Velocity Guns, Version 2 (IBHVG2) simulation program. A new input deck has been added to IBHVG2, which contains the required parameters to identify high-pressure chamber volume, the small chamber's venting method, and gas and solid material discharge coefficients.

The IBHVG2 interior ballistic simulation program, until this modification, could not easily model a dual-chamber gun-mortar system. IBHVG2 was limited to a single chamber size within each simulation. Many current mortar rounds use ignition within a small volume to increase pressure (and thus the burning rate) of the igniter material as a precursor to venting combustion products as an ignition source for a larger volume of propellant in the larger main chamber. The HILO option will allow researchers to model those systems.

2. Physical Description of Mortar Hardware

A very generalized description of the mortar ballistic hardware includes the tube and the mortar round. The tube footplate is positioned solidly on the ground, and the tube is tilted toward the target so that the ballistic arc of the projectile will end at or near the desired point. Mortar projectiles are loaded from the mouth of the tube, aft end first, and ignition occurs when the aft end of the projectile contacts a firing pin at the bottom of the tube. Some mortar rounds can be programmed for different projectile exit velocities by the addition of incremental propelling charges before firing. Figure 1 shows generalized drawings of a mortar system: tube and

footplate, projectile with added propellant packages as "donuts" around the tail boom. Here, the hollow tail boom is used as a high-pressure igniter canister. The projectile and tube drawing also depicts vent holes along the boom and a fixed firing pin at the tube bottom.

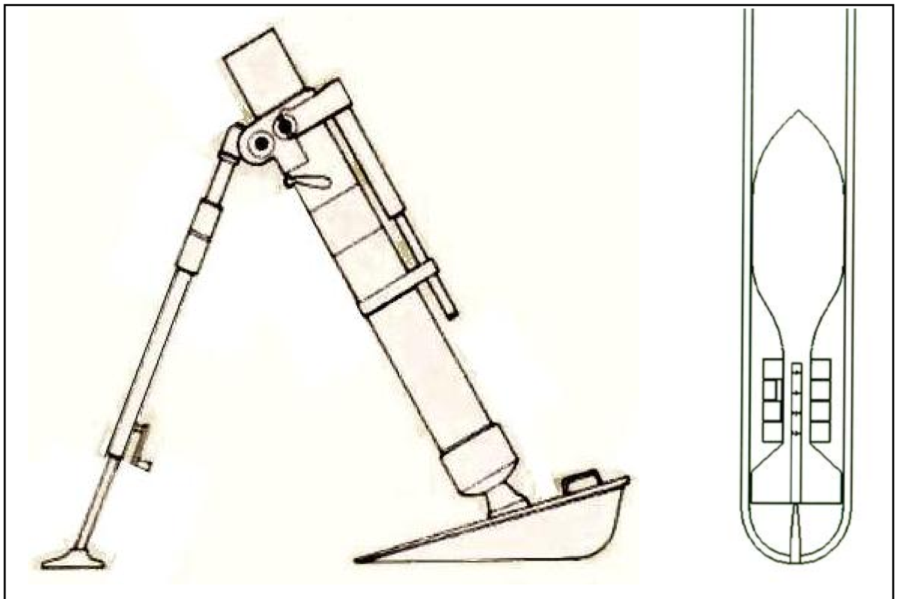

Figure 1. Mortar system (exterior makeup and generic projectile).

In a burst vent mode, the (igniter) propellant and its initial propellant gases are completely contained in a compartment until the pressurizing gas is able to blow out a vent panel between the compartment and the larger volume behind the projectile sealing ring. Then the gas is released to the large volume in order to ignite any other propellants and to accelerate the projectile out of the tube at a pre-programmed velocity. The thickness of the burst disk and its material properties determine the burst pressure required to release the initial combustion gases into the large chamber.

The permeable canister method involves a series of small-diameter vent holes in the igniter container that allow combustion gases to exit into the main chamber. The number of holes and their diameters determine the rate at which gas can escape into the large chamber at any measured pressure differential. The flow of gases through the vents is designed to maintain a relatively higher pressure inside the canister (compared to the large chamber) to keep the initial propellant burning at a faster rate. When propellant particles are smaller than the hole diameters, solid material may be ejected from the canister along with the propellant gases. The hot gases and burning particles ignite any other propellant charges contained in the larger, low-pressure chamber behind the projectile sealing point.

3. Mortar Modeling

3.1 Burst Vent Mode

In the burst vent mode, propellant is contained in a completely closed canister within the large chamber. The large chamber is defined as tube volume behind the “sealing ring” of the projectile, minus the projectile volume aft of the sealing point. When the initial propellant charge starts to burn, all gases are kept within the canister until its interior pressure reaches enough force to burst a vent disk; then hot combustion gases and remaining propellant are exposed to the large chamber.

Within IBHVG2 (*1*), initial combustion is calculated within the small (high-pressure) chamber containing the initial propellant. When the small chamber attains enough internal pressure to rupture the vent disk, internal volume is set to the sum of the high- and low-pressure chambers, interior pressure is now computed with all propellant gases in the new volume, and other propellants (if any) are allowed to ignite and burn in the larger chamber.

Base pressure “felt” by the projectile is created by propellant gases in the large (low-pressure) chamber, and projectile movement starts when base pressure is greater than the resistance pressure between the projectile and tube.

3.2 Permeable Canister Mode

In the permeable canister mode, the initial propellant is burned inside a perforated small-volume chamber. Combustion gases are allowed to escape through perforation holes into the larger chamber, where main propellants (if any) are allowed to ignite and burn under conditions specified by the modeler. A burst pressure may be specified to simulate a completely closed canister until interior gases pressurize the volume to a specified level; then combustion products (and possibly propellant particles) are allowed to escape through the canister perforations. Pressure differential between the chambers determines how much combustion gas will be forced through the holes. A “choked flow” condition can result if the differential is greater than the critical condition (*2*) determined by

$$P_{IN} > P_{OUT} * ((\gamma + 1)/2^{\gamma/(\gamma - 1)},$$

in which γ (interior ballistic gamma) is the ratio of specific heats

$$\gamma = c_p / c_{v.}$$

c_p is the total gas specific heat at constant pressure, while c_v is the gas specific heat at constant volume. In this situation, P_{IN} is the gas pressure on the “high-pressure” side of the vent hole, and

P_{OUT} is the measure of pressure on the exit side of the vent hole. Gas flow through the vent holes is computed as

$$m = \rho A V$$

in which ρ, gas density, is defined as $P_{OUT}/R'T_e$; A is the exit area; and V is $M_e * \mathrm{SQRT}(\gamma R'T_e)$. ($R'$ is the gas constant, T_e is the temperature of the gas at the exit, and M_e is the exit gas Mach number.) If we approximate the gas exit temperature with the propellant flame temperature T_f (a reasonable approximation when γ is in the range of most propellant gases, from 1.2 to 1.3), then $R'T_f$ is the propellant force value F, so in this case

$$m = g * P_{OUT} * A * M_e * \mathrm{SQRT}(\gamma / F),$$

in which g is the gas discharge coefficient between 0 (no discharge) and 1 (maximum flow).

The exit gas Mach number M_e is defined as 1.0 when flow is choked but can be calculated for less-than-choked flow from

$$M_e^2 = 2 / (\gamma - 1) * ((P_{IN} / P_{OUT})^{(\gamma - 1)/\gamma} - 1).$$

When flow is choked, exit gas pressure may be higher than the measure of pressure at some distance away from the vent. P_{OUT} can be estimated from the P_{OUT}/P_{IN} ratio as described in an appendix table from reference (*2*), since it is nearly a linear function (*3*) of γ. Therefore, from the ratio values at $\gamma = 1.4$ and $\gamma = 1.3$, the choked exit pressure is

$$P_{OUT} = P_{IN} * (0.7719 - 0.174 * \gamma).$$

Solid propellant particles, if small enough, can also be carried through the holes by the escaping gases. Since IBHVG2 uses a "well-stirred reactor" type approach to combustion, the propellant particles are assumed to be equally spaced within the chamber. In theory, when a portion of the combustion gas travels through the vent holes, the same portion of solid particles will accompany the gas (assuming the particles are small enough to pass through the vent). In practice, some smaller fraction of solid particles will accompany the gas, because of the "slip" condition where moving gases may slide past solids without fully accelerating the particles. This slip is estimated in IBHVG2 by the user-supplied solid discharge coefficient (SDCF).

IBHVG2 uses a five-step Runge-Kutta method to calculate combustion values and interior pressure within set error bounds from one time step to the next. The energetic material within the canister volume burns as a normal propellant under this scheme, and combustion gases are allowed to escape to the large chamber during the process. However, the solid particle discharge is computed at the end of the time step after the gas discharge mass has been determined. During the simulation setup process, an extra zero-mass propellant charge in the large chamber is created for each of the canister propellant types with the ball-type grain shape. Solid mass discharged from the canister is transferred from the canister charge to its corresponding main chamber propellant entity; the new propellant mass continues burning during the next time step as the same type of material but now at the large chamber's lower pressure.

The individual ejected solid particles are of a known mass since IBHVG2 keeps track of grain dimensions during the burning process. To test for discharge size and for later processing, grains are considered to be of a spherical shape (ball-type grain); individual grain mass is maintained. Particles ejected later will not have the same dimensions, since the two chambers have had different pressures over the previous time step. Because IBHVG2 knows the grain sizes and the masses involved (ejected mass and "ghost" charge mass), the number of grains in each mass can be computed by

$$N = m / \rho / v$$

in which m is the mass of propellant, ρ is the propellant density, and v is the grain volume computed from current dimensions. The number of ejected grains and the number of current "ghost" grains are added, and the result is divided into the sum of the two masses to get an averaged grain mass. From the previous equation, solving now for v, an average volume is known, and the "ghost" propellant dimensions are changed to the average values for the next computational time step. This process maintains propellant mass within the simulation and negates the requirement to create a new "ghost" propellant of a different size grain for each ejection of solid particles from the canister.

When the large-chamber pressure is greater than that of the small chamber, gases move from the larger to the smaller volume; solid particles are not allowed to accompany the gases in this situation.

Again, when mean pressure in the large chamber is high enough to move the projectile, the program calculates associated breech and base pressures determined by mean pressure, acceleration of the projectile, and the distance from breech face to projectile base (actually to the projectile and tube "sealing point" from where the large chamber volume is calculated).

4. HILO (high-low) Input Deck

A new input deck has been added to IBHVG2. The HILO deck contains parameters used by the burst vent method and by the permeable canister method of segregating initial combustion into a small volume before releasing propellant gases and/or particles into the main chamber volume.

Deck HILO, as other IBHVG2 input decks, is accessed by the characters $HILO where the $ is in column 1. The HILO parameters begin on the next input line and include

VOLI	Igniter canister volume
NPRP	Number of canister propellant decks (1 = last propellant input deck, 2 = last two propellant input decks, etc.)
DCOF	Gas discharge coefficient ($0 \leq \text{DCOF} \leq 1$)
IBV	Vent type (1 = vent holes, 2 = blowout disk)
BURP	Burst pressure for blowout disk rupture or vent hole opening
NHOL	Number of vent holes for vent type 1
SHOL	Diameter of vent holes
SDCF	Solid particle discharge coefficient ($0 \leq \text{SDCF} \leq 1$)

Depending on choice of units for input (English or metric), VOLI will be in cubic inches or cubic meters, SHOL will be inches or meters, and BURP will be measured in pounds per square inch or in megapascals. The discharge coefficients are dimensionless (fraction of maximum discharge mass); NPRP, NHOL and IBV are integer units.

In order to use the permeable canister mode, values for NHOL, SHOL, and SDCF must all be greater than zero.

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5. Additional IBHVG2 Output Files

The standard IBHVG2 output file contains little information about the high-pressure canister activity beyond that found in the input deck echo, but additional files are created with data from the canister interior. The code prints interior canister information to unit 14 as a secondary output file (the extra file is designated FORT.14 on a UNIX system) if the high-low option is chosen. Unit 9 is also created as an output file containing all the standard print, plus a copy of the high-pressure canister information from unit 14 (if high-low option is chosen) printed after the standard trajectory data and before the run summary. Unit 18 is the trajectory data in a columnar format to be used as graphical input for post-processing.

Canister data from units 9 and 14 include interior mean pressure and mean temperature at time intervals equal to those of the main output print. Combustion gas exhaust rate is included when the permeable canister option is enabled, along with the current total gas and total solid masses expelled. When the burst vent option is chosen, canister data are no longer printed after burst pressure is exceeded.

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6. Subroutine Source Code

The added IBHVG2 subroutines for gas and solid discharge are printed in appendices I and J. They contain references to published locations where the major equations may be verified.

7. Examples

7.1 Igniter Only

The first test case (appendix A) is a mortar tube with propellant in the main chamber—the standard gun configuration. The following three test cases (appendices B, D, and F) all use the same main chamber, primer, propellants, and projectile. Appendices C and E are the canister data auxiliary output files from the test cases in appendices B and D, respectively.

The computation in appendix B uses the same primary information as that in appendix A but includes an interior canister using the burst vent mode. The IBHVG2 primer deck ($PRIM) propellant mass has been reduced by 90% in order to provide canister initial pressurization at approximately 0.722 MPa (just over 100 psi), since the primer mass is now applied to the smaller chamber instead of the large one. Canister interior simulation data are printed as appendix C; this is auxiliary file 14 from the computation. The canister is set to burst at an interior pressure of 3.45 MPa (500 psi), and output to file 14 stops after the canister burst event.

The IBHVG2 run in appendix D uses the permeable canister option but still with the 3.45-MPa burst pressure to begin the combustion gas venting. Appendix E is the canister information (file 14) from the computation of appendix D.

Appendix F's calculation uses the same input data as D but with the addition of the solid particle discharge coefficient. The print is IBHVG2 file 9, including the standard trajectory information and the canister interior data (printed at the end of the trajectory data).

Figure 2 shows the main chamber pressure versus time curves from the four calculations. The solid line (from the IBHVG2 standard gun configuration) takes the most time, since all the propellant burns in the low-pressure chamber.

The burst vent method shows a similar curve but moved backward in time since chamber pressurization was quicker because of initial propellant burning in the smaller chamber. Maximum pressure is approximately the same for these two curves since the calculations are the same once the canister opens.

The permeable canister mode (no solid discharge option) retains all the propellant in the high-pressure container; combustion gases are released to the large chamber through vent pores. Since combustion takes place at a higher pressure, solid propellant burns to gas much more quickly. Total area of the vent pores and pressure differential determine how fast gases escape to the large chamber. In this case, main chamber pressure rises much higher than in the burst vent mode.

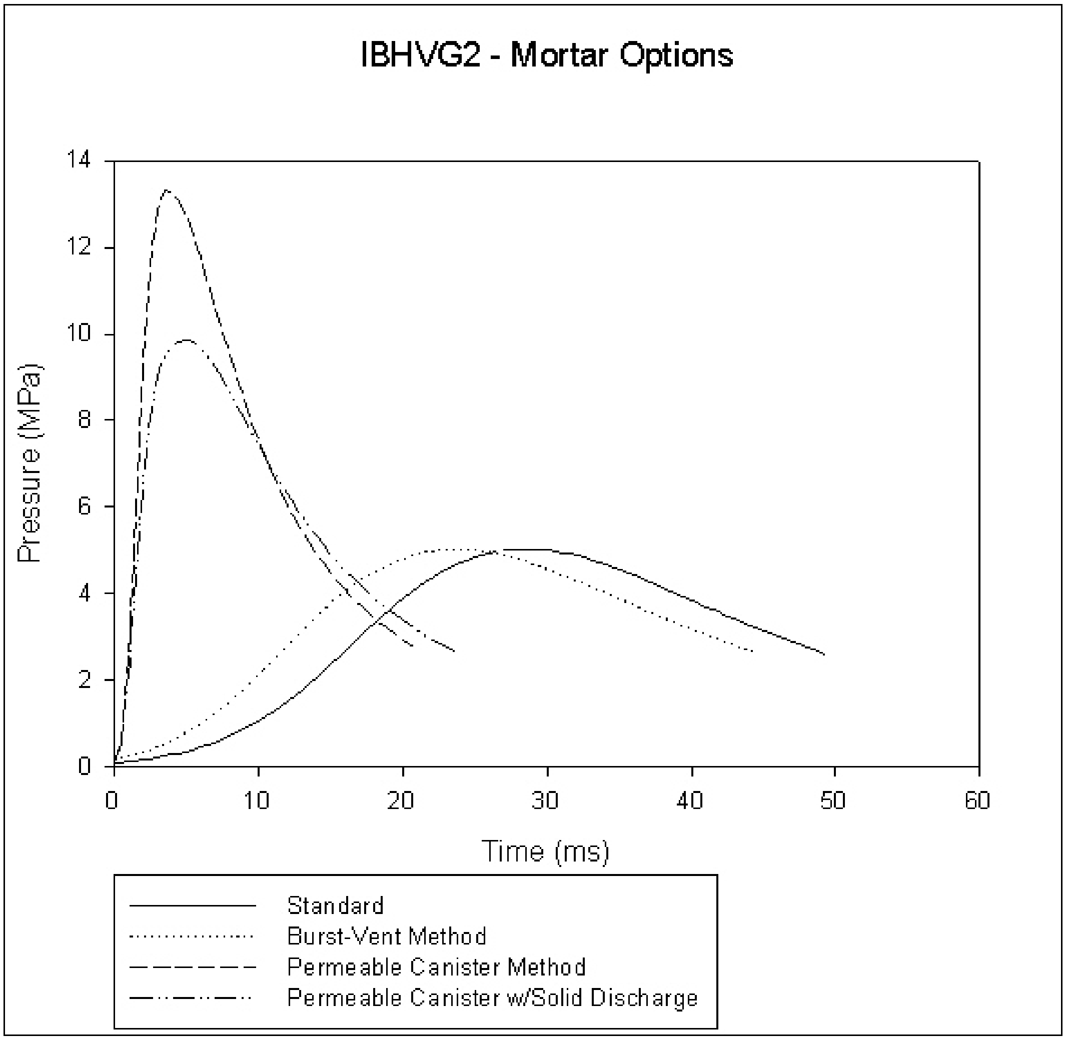

Figure 2. Pressure versus time curves from appendices A, B, D, and F.

When the solid discharge is allowed, a portion of the solid propellant is transported into the low-pressure chamber. After the move is complete, the propellant exhausted to the large chamber burns at a much lower pressure. This is reflected by a lower peak pressure for the calculation. The numeric value of the discharge function determines how much solid propellant is transferred; a low number would result in a high maximum pressure for the calculation, while the opposite is true for a higher solid discharge function value.

Higher mean pressures in the large chamber result in correspondingly higher pressures felt at the base of the projectile, and higher base pressures create higher acceleration forces. In figure 3, the projectile velocities are shown versus time during the four computations from figure 2. Although the total amount of propellant is the same for the burst vent and permeable canister cases, the relatively high pressure within the canister (where the vast majority of the propellant burns) results in a shorter cycle time for the latter cases. The permeable canister mode

calculations impart much higher projectile accelerations and exit velocities because of the higher mean pressures in the main chamber.

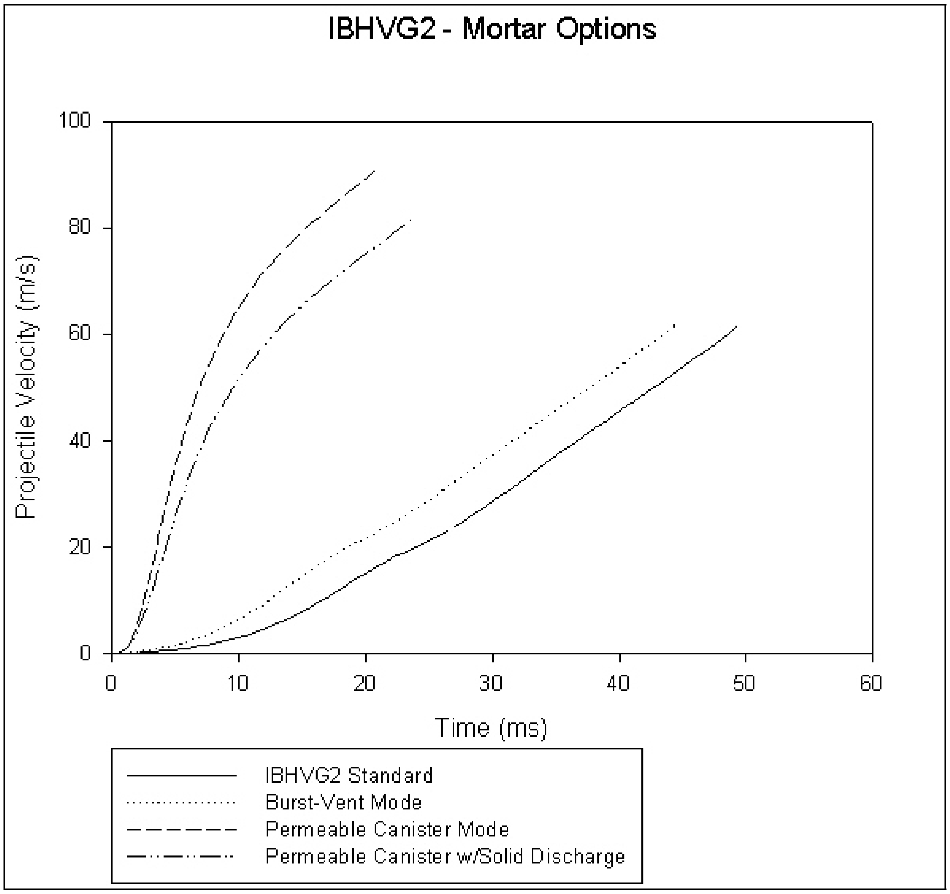

Figure 3. Projectile velocity versus time curves from appendices A, B, D, and F.

Interior pressures from the three canister computations are shown in figure 4. All three pressure curves have the same initial data from the start of the computation to a time of 0.123 ms, when burst pressure has been reached. The burst vent mode data are plotted only until pressure reaches the burst value of 3.45 MPa and the canister computation ceases. Permeable canister computations continue during the rest of the ballistic cycle. With a non-zero solid discharge coefficient, the interior pressures are not as high because some of the propellant has been discharged into the low-pressure chamber.

The printout in appendix F, the permeable canister simulation using a solid discharge coefficient, shows two propelling charges in its input echo section even though there is only one $PROP deck in the input data. The first charge has a mass of 0.0 kg and is the “ghost” propellant waiting to be filled by the solid discharge particles during the computation. The second charge is the canister propellant with an initial mass of 0.6 kg. The igniter data, shown after the standard IBHVG2 trajectory information, exhibit a final mass for the “ghost” propellant (printed under the heading SLD EXIT 1) of 0.0177 kg. This is the total mass of solid particles exhausted from the

canister to the main chamber. The last value under the heading "G MASS OUT" is the final mass of combustion gases emitted from the canister (0.04 kg by the end of the computation).

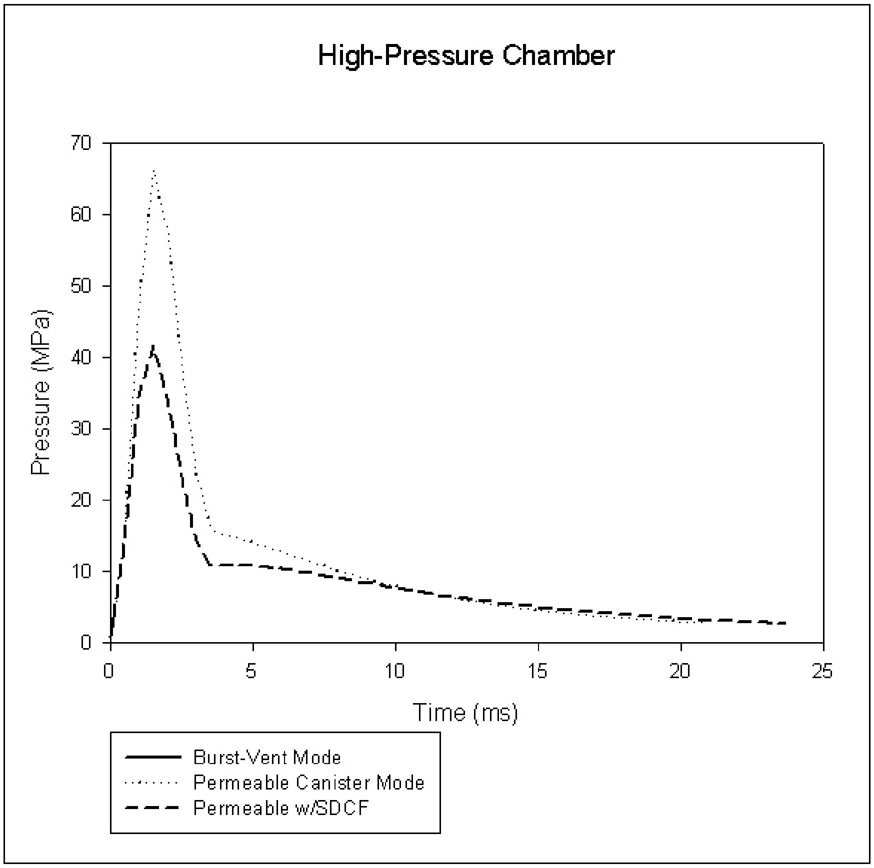

Figure 4. Canister interior pressures.

7.2 Igniter Plus Main Propellant

When additional propellants are added to the mortar round (as an integral part of the round or as add-on segments for the main chamber), the canister propellant becomes primarily an igniter for the ballistic cycle. The small canister volume provides relatively high-pressure hot gases which quickly raise the temperature and pressure of the main chamber where the main charge ignites and gets an initial boost to its burning rate. In IBHVG2 simulations, these additional main charges are added as $PROP decks before the canister propellants are defined (canister propellants are the last "N" propellants decks in the input file).

Figure 5 shows main chamber pressure for four simulations: an IBHVG2 standard chamber simulation and three additional calculations with permeable canisters and non-zero solid discharge coefficients (0.02, 0.04 and 0.06). All four computations contain the same mass of canister propellant and main charge. Appendix G is the output file from the simulation of a mortar round with added main chamber propellant calculated as a standard main-chamber-only

configuration. (Primer mass has been added as in appendix A to start combustion at near atmospheric pressure.) The pressure time curve for the simulation is plotted as a solid line.

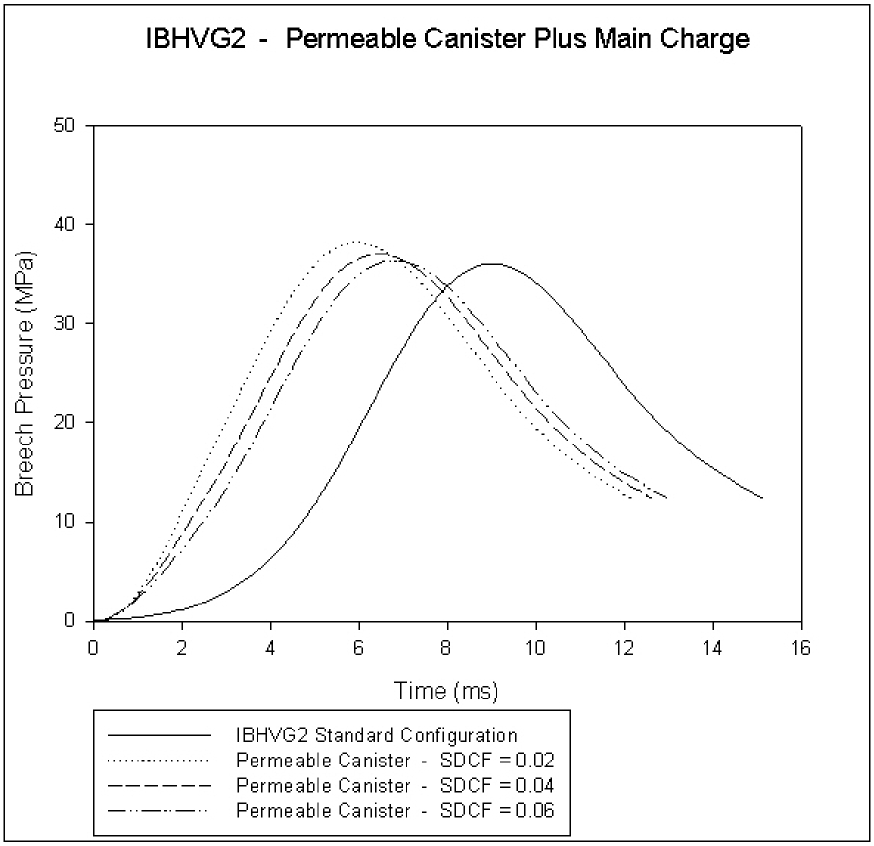

Figure 5. Parametric study of solid discharge coefficient - pressures.

Appendix H is the comparable permeable canister calculation with a solid discharge coefficient of 0.06 value. Combustion gases exit to the main chamber through vents that open at an internal pressure of 3.45 MPa (500 psi). Total solid mass discharged from the canister into the large chamber during the computation was 0.0317 kg, while mass of discharged combustion gases was only 0.0271 kg. As can be seen in figure 5, as the value of the solid discharge coefficient rises, the simulation approaches the IBHVG2 standard configuration (appendix G).

Projectile velocity versus time curves for the four cases are plotted in figure 6. Again, as the value of the discharge coefficient rises, the computed permeable canister simulation curves approach the standard plotted data.

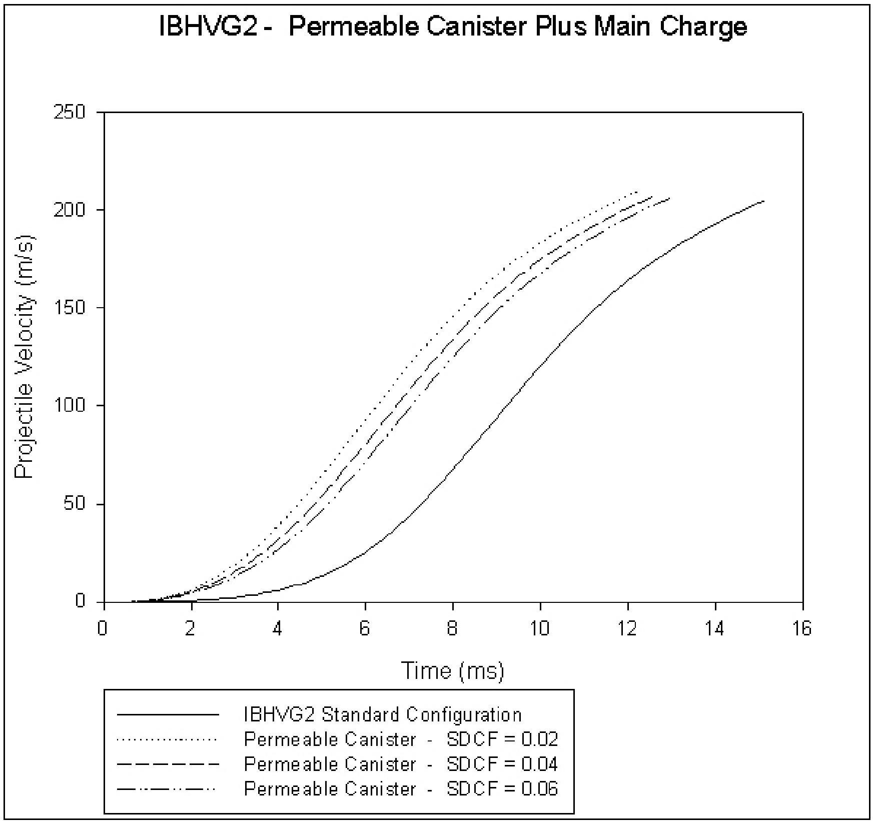

Figure 6. Parametric study of solid discharge coefficient – projectile velocities.

8. Summary

The simulation of high-low pressure chambers on mortar systems has been added to the IBHVG2 program. An independently calculated canister volume can be added to the standard configuration to assist combustion of igniter gases and thus to increase the rate of pressure rise in the main chamber. A canister burst pressure parameter allows the modeler to approximate the closed canister initial pressurization and to simulate addition of igniter gases to the main chamber at a later time in the ballistic cycle. Vent hole size, the number of holes, and pressure differentials control the release of ignition gases and solid propellant particles to the main chamber. Discharge coefficients for gas and solid matter allow the modeler to tune the simulation to match actual test data.

9. References

1. Anderson, R. D.; Fickie, K. D. *IBHVG2 – A User's Guide*; BRL-TR-2928; U.S. Army Ballistic Research Laboratory: Aberdeen Proving Ground, MD, July 1987.

2. John, J. E. A. *Gas Dynamics*, Second Edition; LCCCN 83-15467; Ally and Bacon, Inc., 1984, 49-53.

3. Shapiro, A. H. *The Dynamics and Thermodynamics of Compressible Fluid Flow*, Volume I; LCCCN 53-8869; The Ronald Press Company: New York, 1953, 84.

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Appendix A. IBHVG2 Standard Gun Mode

```
 ERRTOL =     0.119209E-06



                                    IBHVG2.506d.HILO  DATE:              TIME:

0 CARD   1 --> $GUN
  CARD   2 -->      NAME='MORTAR' CHAM=0.0032283 GRVE=0.1219  LAND=0.1219
  CARD   3 -->      TRAV=1.1811  G/L=1.0000  TWST=999.0
  CARD   4 --> $INFO
  CARD   5 -->      DELT=0.12500E-04  DELP=0.50000E-03  INP=2  OUT=2
  CARD   6 -->      POPT=1,1,1,0,1,1  RUN='MORTAR'
  CARD   7 --> $RESI
  CARD   8 -->      NPTS=3  TRAV=0.0,   0.1524,   1.1684
  CARD   9 -->              PRES=0.0,   3.4474,   0.3447
  CARD  10 --> $PROJ
  CARD  11 -->      PRWT=14.0614
  CARD  12 --> $PRIM
  CARD  13 -->      NAME='BPPELLETS'  GAMA=1.2500    FORC=313852.0  COV=0.87789E-03
  CARD  14 -->      TEMP=2380.0       CHWT=0.0010115
  CARD  15 --> $COMM   HILO
  CARD  16 -->      IBV=2 NHOL=28 SHOL=.005301 NPRP=1 VOLI=0.00009793
  CARD  17 -->      DCOF=.84 BURP=3.4473  $ SDCF=0.02
  CARD  18 --> $PROP
  CARD  19 -->      NAME='CAN PROP'  RHO=1550.1  GAMA=1.2100   FORC=1169024.1
  CARD  20 -->      COV=0.96532E-03  TEMP=3720.0  CHWT=0.0600   ALPH=0.9035
  CARD  21 -->      BETA=0.0020624   GRAN='BALL'  DIAM=0.0012446    NTBL=0
  CARD  22 --> $END
```

```
------------
- GUN TUBE -
------------

TYPE: MORTAR                   CHAMBER VOLUME (M3): 0.00323   TRAVEL (M):           1.18110
GROOVE DIAMETER (M):   0.12190   LAND DIAMETER (M):   0.12190   GROOVE/LAND RATIO (-): 1.000
TWIST (CALS/TURN):     999.0     BORE AREA (M2):      0.01167   HEAT-LOSS OPTION:      1
SHELL THICKNESS (M):   0.000102  SHELL CP (J/KG-K):   460.3161  SHELL DENSITY (KG/M3): 7861.0913
INITIAL SHELL TEMP (K): 293.     AIR H0 (W/M**2-K):   11.3482

--------------
- PROJECTILE -
--------------

TYPE:                            TOTAL WEIGHT (KG):   14.061    WEIGHT PREDICTOR OPTION: 0

--------------
- RESISTANCE -
--------------

AIR RESISTANCE OPTION:  1  TUBE GAS INITIAL PRES (MPA)  0.000   WALL HEATING FRACTION:  0.000
RESISTIVE PRESSURE MULT INDEX:    3   RESISTIVE FACTOR  1.000   FRICTION TABLE LENGTH:  3

 I   TRAVEL (M)  PRESSURE (MPA)  I  TRAVEL (M)  PRESSURE (MPA)  I  TRAVEL (M)  PRESSURE (MPA)

 1      0.000         0.000      2      0.152        3.447      3      1.168         0.345

-----------
- GENERAL -
-----------

MAX TIME STEP (S):  0.000012   PRINT STEP (S):     0.000500  MAX RELATIVE ERROR (-):   0.00200
PRINT OPTIONS:     1 1 1 0 1 1      STORE OPTION:  0         CONSTANT-PRESSURE OPTION:  0
GRADIENT MODEL: LAGRANGIAN          INPUT UNITS:   METRIC    OUTPUT UNITS:             METRIC

----------
- RECOIL -
----------

RECOIL OPTION:       0           TYPE:                   RECOILING WEIGHT (KG):  0.

----------
- PRIMER -
----------

TYPE: BPPELLETS                 GAMMA (-):       1.2500    FORCE (J/KG):      313852.
COVOLUME (M3/KG): 8.7789E-04    FLAME TEMP (K):  2380.0    WEIGHT (KG):      0.001012
```



```
-------------
- CHARGE  1 -
-------------

TYPE: CAN PROP                GRAINS:           38345.  BALL     WEIGHT (KG):  0.0600
EROSIVE COEFF (-):   0.000000  CHARGE IGN CODE:  0       CHARGE IGN AT (S):   0.00000E+00
GRAIN DIAMETER (M):  0.001245
```

	PROPERTIES AT LAYER BOUNDARIES OF 1ST	2ND	3RD	LAT SURFACES 4TH
AT DEPTH (M):	------	------	------	0.0000E+00
ADJACENT LAYER WT %:	------	------	------	100.000
DENSITY (KG/M3):	------	------	------	1550.100
GAMMA (-):	------	------	------	1.2100
FORCE (J/KG):	------	------	------	1169024.
COVOLUME (M3/KG):	------	------	------	9.6532E-04
FLAME TEMP (K):	------	------	------	3720.0
BURNING RATE EXPS:	------	------	------	0.9035
BURNING RATE COEFFS:	------	------	------	2.0624E-03

MORTAR IBHVG2.506d.HILO DATE: TIME:

TIME (MS)	TRAV (M)	VEL (M/S)	ACC (G)	BREECH PRESS (MPA)	MEAN PRESS (MPA)	BASE PRESS (MPA)	MEAN TEMP (K)	FRAC BURN 1
0 0.000	0.000	0.00	8.	0.100	0.100	0.099	2380.	0.000
0.500	0.000	0.04	10.	0.115	0.115	0.115	2511.	0.001
BARREL RESISTANCE OVERCOME - PROJECTILE MOVING								
1.000	0.000	0.10	11.	0.132	0.132	0.132	2632.	0.001
1.500	0.000	0.15	13.	0.151	0.151	0.151	2742.	0.002
2.000	0.000	0.22	14.	0.173	0.173	0.173	2842.	0.003
2.500	0.000	0.29	16.	0.197	0.197	0.197	2932.	0.004
3.000	0.000	0.38	18.	0.224	0.224	0.223	3013.	0.006
3.500	0.001	0.47	20.	0.254	0.253	0.253	3085.	0.007
4.000	0.001	0.57	22.	0.287	0.287	0.286	3150.	0.008
4.500	0.001	0.69	25.	0.324	0.323	0.323	3208.	0.010
5.000	0.002	0.82	28.	0.364	0.364	0.364	3259.	0.012
5.500	0.002	0.96	31.	0.410	0.409	0.409	3305.	0.014
6.000	0.003	1.12	34.	0.459	0.459	0.458	3346.	0.016
6.500	0.003	1.29	37.	0.514	0.513	0.513	3381.	0.019
7.000	0.004	1.48	41.	0.573	0.573	0.572	3413.	0.022
7.500	0.005	1.69	45.	0.639	0.638	0.637	3441.	0.025
8.000	0.006	1.92	49.	0.710	0.709	0.708	3466.	0.028
8.500	0.007	2.17	54.	0.787	0.786	0.786	3487.	0.032
9.000	0.008	2.45	59.	0.871	0.870	0.869	3506.	0.036
9.500	0.009	2.75	64.	0.961	0.960	0.959	3522.	0.041
10.000	0.011	3.07	69.	1.058	1.057	1.056	3536.	0.045
10.500	0.012	3.43	75.	1.161	1.161	1.159	3549.	0.051
11.000	0.014	3.81	81.	1.272	1.271	1.270	3559.	0.056
11.500	0.016	4.22	87.	1.389	1.389	1.387	3567.	0.063
12.000	0.018	4.66	93.	1.513	1.513	1.511	3574.	0.069
12.500	0.021	5.13	99.	1.644	1.643	1.641	3580.	0.076
13.000	0.023	5.63	106.	1.780	1.779	1.777	3584.	0.084
13.500	0.026	6.16	112.	1.922	1.921	1.919	3587.	0.092
14.000	0.029	6.73	118.	2.069	2.068	2.066	3589.	0.101
14.500	0.033	7.32	124.	2.220	2.219	2.216	3590.	0.110
15.000	0.037	7.95	130.	2.374	2.373	2.371	3590.	0.120
15.500	0.041	8.60	135.	2.531	2.530	2.528	3589.	0.130
16.000	0.045	9.27	140.	2.690	2.689	2.686	3587.	0.141
16.500	0.050	9.97	144.	2.849	2.848	2.845	3584.	0.152
17.000	0.055	10.68	148.	3.008	3.006	3.004	3580.	0.164
17.500	0.061	11.42	150.	3.165	3.163	3.161	3576.	0.176
18.000	0.067	12.16	152.	3.319	3.318	3.315	3571.	0.188
18.500	0.073	12.91	153.	3.470	3.469	3.466	3565.	0.201
19.000	0.080	13.66	153.	3.617	3.615	3.613	3559.	0.215
19.500	0.087	14.40	151.	3.758	3.757	3.754	3552.	0.228
20.000	0.094	15.14	148.	3.893	3.892	3.889	3545.	0.242
20.500	0.102	15.86	144.	4.021	4.020	4.018	3537.	0.257
21.000	0.110	16.55	139.	4.143	4.142	4.139	3529.	0.271
21.500	0.118	17.22	133.	4.257	4.256	4.253	3521.	0.286
22.000	0.127	17.85	125.	4.363	4.362	4.360	3512.	0.300
22.500	0.136	18.44	116.	4.461	4.460	4.458	3503.	0.315
23.000	0.146	18.98	106.	4.552	4.551	4.550	3494.	0.330
23.500	0.155	19.48	100.	4.636	4.635	4.633	3485.	0.345
24.000	0.165	19.99	109.	4.712	4.711	4.709	3476.	0.360
24.500	0.175	20.55	118.	4.781	4.780	4.777	3467.	0.375
25.000	0.186	21.15	126.	4.841	4.840	4.838	3457.	0.390
25.500	0.196	21.78	133.	4.894	4.892	4.890	3448.	0.405
26.000	0.207	22.45	139.	4.938	4.937	4.934	3438.	0.419
26.500	0.219	23.15	145.	4.974	4.972	4.970	3428.	0.434
27.000	0.231	23.87	151.	5.001	5.000	4.998	3418.	0.448
27.500	0.243	24.62	155.	5.021	5.020	5.017	3407.	0.463
28.000	0.255	25.39	159.	5.033	5.031	5.029	3397.	0.477

28.500	0.268	26.18	163.	5.037	5.035	5.032	3386.	0.490
28.513	0.268	26.20	163.	5.037	5.035	5.032	3386.	0.491
LOCAL PRESSURE MAX DETECTED								
29.000	0.281	26.99	166.	5.033	5.032	5.029	3375.	0.504
29.500	0.295	27.81	169.	5.022	5.021	5.018	3363.	0.517
30.000	0.309	28.65	171.	5.005	5.003	5.000	3352.	0.530
30.500	0.324	29.49	173.	4.981	4.979	4.977	3340.	0.543
31.000	0.339	30.34	174.	4.951	4.950	4.947	3328.	0.555
31.500	0.354	31.19	175.	4.916	4.914	4.911	3316.	0.568
32.000	0.370	32.05	176.	4.875	4.874	4.871	3303.	0.579
32.500	0.386	32.91	176.	4.830	4.829	4.826	3291.	0.591
33.000	0.403	33.78	176.	4.781	4.779	4.776	3278.	0.602
33.500	0.420	34.64	176.	4.727	4.726	4.723	3265.	0.613
34.000	0.437	35.50	176.	4.671	4.669	4.666	3252.	0.624
34.500	0.455	36.36	175.	4.611	4.609	4.606	3239.	0.634
35.000	0.474	37.22	175.	4.549	4.547	4.544	3226.	0.644
35.500	0.493	38.07	174.	4.484	4.482	4.479	3212.	0.654
36.000	0.512	38.92	173.	4.417	4.416	4.413	3199.	0.663
36.500	0.532	39.77	172.	4.349	4.348	4.345	3185.	0.672
37.000	0.552	40.61	172.	4.280	4.278	4.275	3172.	0.681
37.500	0.572	41.45	171.	4.209	4.208	4.205	3158.	0.689
38.000	0.593	42.29	170.	4.138	4.136	4.133	3144.	0.697
38.500	0.614	43.13	170.	4.066	4.064	4.061	3130.	0.705
39.000	0.636	43.96	169.	3.994	3.992	3.989	3117.	0.713
39.500	0.658	44.79	169.	3.921	3.920	3.917	3103.	0.720
40.000	0.681	45.61	169.	3.849	3.847	3.844	3089.	0.728
40.500	0.704	46.44	168.	3.776	3.775	3.772	3075.	0.735
41.000	0.727	47.26	168.	3.704	3.703	3.700	3061.	0.741
41.500	0.751	48.09	168.	3.633	3.632	3.629	3047.	0.748
42.000	0.776	48.92	169.	3.562	3.561	3.558	3033.	0.754
42.500	0.800	49.74	169.	3.492	3.490	3.487	3019.	0.760
43.000	0.825	50.57	169.	3.422	3.421	3.418	3005.	0.766
43.500	0.851	51.41	170.	3.353	3.352	3.349	2991.	0.772
44.000	0.877	52.24	171.	3.285	3.284	3.281	2978.	0.777
44.500	0.903	53.09	172.	3.218	3.216	3.213	2964.	0.782
45.000	0.930	53.93	173.	3.152	3.150	3.147	2950.	0.787
45.500	0.957	54.79	175.	3.086	3.085	3.082	2936.	0.792
46.000	0.985	55.65	177.	3.022	3.021	3.018	2922.	0.797
46.500	1.013	56.52	178.	2.959	2.957	2.954	2908.	0.802
47.000	1.041	57.40	181.	2.897	2.895	2.892	2894.	0.806
47.500	1.070	58.29	183.	2.836	2.834	2.831	2880.	0.810
48.000	1.099	59.19	185.	2.776	2.774	2.771	2866.	0.814
48.500	1.129	60.11	188.	2.716	2.715	2.712	2852.	0.818
49.000	1.160	61.04	191.	2.659	2.657	2.654	2838.	0.822
49.350	1.181	61.69	190.	2.618	2.617	2.614	2829.	0.825

PROJECTILE EXIT

MORTAR IBHVG2.506d.HILO DATE: TIME:

CONDITIONS AT:	METRIC PMAX	METRIC MUZZLE	ENGLISH PMAX	ENGLISH MUZZLE
TIME (MS):	28.500	49.350		
TRAVEL (M):	0.2681	1.1811		
VELOCITY (M/S)	26.18	61.69		202.
ACCELERATION (G):	163.	190.		
BREECH PRESS (MPA):	5.0365	2.6185	730.	
MEAN PRESS (MPA):	5.0351	2.6169		
BASE PRESS (MPA):	5.0323	2.6136		
MEAN TEMP (K):	3386.	2829.		
Z CHARGE 1 (-):	0.490	0.825		

ENERGY BALANCE SUMMARY	JOULE	%
TOTAL CHEMICAL:	276801.	100.00
(1) INTERNAL GAS:	211020.	76.24
(2) WORK AND LOSSES:	65781.	23.76
(A) PROJECTILE KINETIC:	26759.	9.67
(B) GAS KINETIC:	39.	0.01
(C) PROJECTILE ROTATIONAL:	0.	0.00
(D) FRICTIONAL WORK TO TUBE:	0.	0.00
(E) OTHER FRICTIONAL WORK:	25599.	9.25
(F) WORK DONE AGAINST AIR:	240.	0.09
(G) HEAT CONVECTED TO BORE:	13144.	4.75
(H) RECOIL ENERGY:	0.	0.00

LOADING DENSITY (KG/M3):	18.899
CHARGE WT/PROJECTILE WT:	0.004
PIEZOMETRIC EFFICIENCY:	0.385
EXPANSION RATIO:	5.270

Appendix B. Burst Vent Canister Mode

```
 ERRTOL =    0.119209E-06


                                 IBHVG2.506d.HILO  DATE:              TIME:

0 CARD   1 --> $GUN
  CARD   2 -->      NAME='MORTAR' CHAM=0.0032283 GRVE=0.1219  LAND=0.1219
  CARD   3 -->      TRAV=1.1811  G/L=1.0000  TWST=999.0
  CARD   4 --> $INFO
  CARD   5 -->      DELT=0.12500E-04  DELP=0.50000E-03  INP=2  OUT=2
  CARD   6 -->      POPT=1,1,1,0,1,1  RUN='MORTAR'
  CARD   7 --> $RESI
  CARD   8 -->      NPTS=3  TRAV=0.0,   0.1524,   1.1684
  CARD   9 -->              PRES=0.0,   3.4474,   0.3447
  CARD  10 --> $PROJ
  CARD  11 -->      PRWT=14.0614
  CARD  12 --> $PRIM
  CARD  13 -->      NAME='BPPELLETS'  GAMA=1.2500    FORC=313852.0  COV=0.87789E-03
  CARD  14 -->      TEMP=2380.0       CHWT=0.00010115
  CARD  15 --> $HILO
  CARD  16 -->      IBV=2 NHOL=28 SHOL=.005301 NPRP=1 VOLI=0.00009793
  CARD  17 -->      DCOF=.84 BURP=3.4473  $ SDCF=0.02
  CARD  18 --> $PROP
  CARD  19 -->      NAME='CAN PROP'  RHO=1550.1  GAMA=1.2100   FORC=1169024.1
  CARD  20 -->      COV=0.96532E-03  TEMP=3720.0  CHWT=0.0600   ALPH=0.9035
  CARD  21 -->      BETA=0.0020624   GRAN='BALL'  DIAM=0.0012446    NTBL=0
  CARD  22 --> $END
```

```
MORTAR                         IBHVG2.506d.HILO  DATE:              TIME:

------------
- GUN TUBE -
------------

TYPE: MORTAR                   CHAMBER VOLUME (M3):  0.00323   TRAVEL (M):            1.18110
GROOVE DIAMETER (M): 0.12190   LAND DIAMETER (M):    0.12190   GROOVE/LAND RATIO (-): 1.000
TWIST (CALS/TURN):   999.0     BORE AREA (M2):       0.01167   HEAT-LOSS OPTION:      1
SHELL THICKNESS (M)  0.000102  SHELL CP (J/KG-K):    460.3161  SHELL DENSITY (KG/M3): 7861.0913
INITIAL SHELL TEMP (K): 293.      AIR H0 (W/M**2-K):    11.3482

--------------
- PROJECTILE -
--------------

TYPE:                      TOTAL WEIGHT (KG):  14.061   WEIGHT PREDICTOR OPTION: 0

--------------
- RESISTANCE -
--------------

AIR RESISTANCE OPTION:  1   TUBE GAS INITIAL PRES (MPA)  0.000  WALL HEATING FRACTION: 0.000
RESISTIVE PRESSURE MULT INDEX:  3   RESISTIVE FACTOR     1.000  FRICTION TABLE LENGTH:   3

 I   TRAVEL (M)  PRESSURE (MPA)  I  TRAVEL (M)  PRESSURE (MPA)  I  TRAVEL (M)  PRESSURE (MPA)

 1     0.000         0.000       2     0.152        3.447       3     1.168        0.345

-----------
- GENERAL -
-----------

MAX TIME STEP (S):    0.000012    PRINT STEP (S):  0.000500  MAX RELATIVE ERROR (-): 0.00200
PRINT OPTIONS:       1 1 1 0 1 1  STORE OPTION:    0         CONSTANT-PRESSURE OPTION:  0
GRADIENT MODEL: LAGRANGIAN     INPUT UNITS:        METRIC    OUTPUT UNITS:          METRIC

----------
- RECOIL -
----------

  RECOIL OPTION:           0           TYPE:                     RECOILING WEIGHT (KG):  0.

-----------------------
- HILO/PRIMER IGNITER -
-----------------------

IGNITER HAS  28 HOLES OF    0.0053010 M DIAMETER
LAST PROPELLANT BURNS IN THE IGNITER
IGNITER VOLUME IS   0.00009793 M3
GAS DISCHARGE COEFFICIENT IS  0.8400
SOLID DISCHARGE COEFFICIENT IS  0.0000
BURST PRESSURE TO START VENTING OR BURST IS        3.447 MPA
VENT/BURST SWITCH (1=VENT, 2=BURST) IS 2
```

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----------
- PRIMER -
----------

TYPE: BPPELLETS                  GAMMA (-):        1.2500    FORCE (J/KG):   313852.
COVOLUME (M3/KG):  8.7789E-04   FLAME TEMP (K):   2380.0    WEIGHT (KG):    0.000101

-------------
- CHARGE  1 -
-------------

TYPE: CAN PROP               GRAINS:          38345.   BALL  WEIGHT (KG):       0.0600
EROSIVE COEFF (-): 0.000000  CHARGE IGN CODE:        0       CHARGE IGN AT (S): 0.00000E+00
GRAIN DIAMETER (M): 0.001245

                        PROPERTIES AT LAYER BOUNDARIES OF  LAT SURFACES
                             1ST         2ND         3RD         4TH

AT DEPTH (M):              ------      ------      ------  0.0000E+00
ADJACENT LAYER WT %:       ------      ------      ------     100.000
DENSITY (KG/M3):           ------      ------      ------    1550.100
GAMMA (-):                 ------      ------      ------      1.2100
FORCE (J/KG):              ------      ------      ------    1169024.
COVOLUME (M3/KG):          ------      ------      ------  9.6532E-04
FLAME TEMP (K):            ------      ------      ------      3720.0
BURNING RATE EXPS:         ------      ------      ------      0.9035
BURNING RATE COEFFS:       ------      ------      ------  2.0624E-03
```

```
MORTAR                     IBHVG2.506d.HILO  DATE:              TIME:

   TIME   TRAV    VEL      ACC   BREECH     MEAN     BASE     MEAN  FRAC
   (MS)    (M)    (M/S)    (G)    PRESS    PRESS    PRESS     TEMP  BURN
                                  (MPA)    (MPA)    (MPA)     (K)     1
0 0.000  0.000    0.00      9.    0.102    0.102    0.102     293. 0.000
  0.009  0.000    0.00      9.    0.102    0.102    0.102     293. 0.000
 LOCAL PRESSURE MAX DETECTED
 BARREL RESISTANCE OVERCOME - PROJECTILE MOVING
  0.123  0.000    0.01      9.    0.102    0.102    0.102     293. 0.002
 LOCAL PRESSURE MIN DETECTED
 IGNITER HAS BURST
  0.500  0.000    0.07     18.    0.208    0.208    0.207     560. 0.003
  1.000  0.000    0.16     21.    0.247    0.247    0.247     654. 0.004
  1.500  0.000    0.28     24.    0.293    0.293    0.292     757. 0.006
  2.000  0.000    0.40     28.    0.344    0.344    0.343     868. 0.008
  2.500  0.001    0.55     33.    0.402    0.402    0.401     986. 0.010
  3.000  0.001    0.73     38.    0.466    0.466    0.465    1109. 0.012
  3.500  0.001    0.92     43.    0.538    0.538    0.537    1236. 0.014
  4.000  0.002    1.15     49.    0.617    0.616    0.615    1366. 0.017
  4.500  0.002    1.40     55.    0.703    0.702    0.701    1497. 0.021
  5.000  0.003    1.68     61.    0.796    0.796    0.795    1626. 0.025
  5.500  0.004    2.00     68.    0.897    0.897    0.896    1753. 0.029
  6.000  0.005    2.35     75.    1.006    1.006    1.004    1877. 0.033
  6.500  0.007    2.73     82.    1.123    1.122    1.121    1996. 0.039
  7.000  0.008    3.16     90.    1.247    1.246    1.244    2109. 0.044
  7.500  0.010    3.62     98.    1.378    1.377    1.375    2215. 0.050
  8.000  0.012    4.11    106.    1.516    1.515    1.513    2316. 0.057
  8.500  0.014    4.65    114.    1.661    1.660    1.658    2409. 0.064
  9.000  0.016    5.23    122.    1.812    1.811    1.809    2495. 0.072
  9.500  0.019    5.85    130.    1.968    1.967    1.965    2574. 0.080
 10.000  0.022    6.50    137.    2.130    2.129    2.126    2647. 0.089
 10.500  0.026    7.19    145.    2.295    2.294    2.291    2713. 0.099
 11.000  0.029    7.92    152.    2.463    2.462    2.459    2773. 0.109
 11.500  0.033    8.68    158.    2.633    2.631    2.629    2827. 0.120
 12.000  0.038    9.47    164.    2.803    2.802    2.799    2875. 0.131
 12.500  0.043   10.29    169.    2.973    2.972    2.969    2919. 0.143
 13.000  0.048   11.12    173.    3.141    3.140    3.137    2957. 0.155
 13.500  0.054   11.98    176.    3.306    3.305    3.302    2991. 0.168
 14.000  0.060   12.84    177.    3.467    3.466    3.463    3021. 0.181
 14.500  0.067   13.71    178.    3.623    3.621    3.618    3047. 0.194
 15.000  0.074   14.58    177.    3.772    3.770    3.767    3069. 0.208
 15.500  0.081   15.44    174.    3.914    3.912    3.909    3089. 0.223
 16.000  0.089   16.29    170.    4.048    4.046    4.044    3106. 0.237
 16.500  0.098   17.11    165.    4.174    4.172    4.169    3120. 0.252
 17.000  0.107   17.90    158.    4.290    4.289    4.286    3131. 0.267
 17.500  0.116   18.66    150.    4.398    4.397    4.394    3141. 0.282
 18.000  0.125   19.37    140.    4.497    4.496    4.494    3149. 0.297
 18.500  0.135   20.03    129.    4.587    4.586    4.584    3155. 0.313
 19.000  0.145   20.63    116.    4.668    4.667    4.665    3160. 0.328
 19.500  0.156   21.17    109.    4.741    4.740    4.739    3163. 0.343
 20.000  0.166   21.73    118.    4.807    4.806    4.804    3166. 0.359
 20.500  0.177   22.32    125.    4.863    4.862    4.860    3167. 0.374
 21.000  0.189   22.96    132.    4.912    4.911    4.909    3167. 0.389
 21.500  0.200   23.62    139.    4.952    4.951    4.949    3167. 0.404
 22.000  0.212   24.31    144.    4.984    4.983    4.980    3165. 0.419
 22.500  0.225   25.04    150.    5.008    5.006    5.004    3163. 0.433
 23.000  0.237   25.78    154.    5.023    5.022    5.019    3160. 0.448
 23.500  0.250   26.55    158.    5.031    5.029    5.027    3156. 0.462
 23.750  0.257   26.93    160.    5.032    5.030    5.028    3154. 0.469
 LOCAL PRESSURE MAX DETECTED
 24.000  0.264   27.33    161.    5.031    5.029    5.027    3152. 0.476
 24.500  0.278   28.13    164.    5.023    5.022    5.019    3146. 0.490
```

25.000	0.292	28.94	167.	5.009	5.008	5.005	3141.	0.504
25.500	0.307	29.76	169.	4.988	4.987	4.984	3134.	0.517
26.000	0.322	30.60	170.	4.961	4.960	4.957	3127.	0.530
26.500	0.337	31.43	172.	4.929	4.927	4.924	3120.	0.542
27.000	0.353	32.28	173.	4.891	4.889	4.886	3112.	0.555
27.500	0.370	33.13	173.	4.848	4.846	4.843	3104.	0.567
28.000	0.386	33.97	173.	4.800	4.799	4.796	3095.	0.578
28.500	0.404	34.82	173.	4.749	4.748	4.745	3086.	0.590
29.000	0.421	35.67	173.	4.694	4.693	4.690	3077.	0.601
29.500	0.439	36.52	173.	4.636	4.635	4.632	3067.	0.611
30.000	0.458	37.37	173.	4.575	4.574	4.571	3057.	0.622
30.500	0.477	38.22	172.	4.512	4.510	4.507	3047.	0.632
31.000	0.496	39.06	172.	4.446	4.445	4.442	3036.	0.642
31.500	0.516	39.90	171.	4.379	4.378	4.375	3026.	0.651
32.000	0.536	40.74	170.	4.311	4.309	4.306	3015.	0.661
32.500	0.556	41.57	170.	4.241	4.240	4.237	3003.	0.669
33.000	0.577	42.40	169.	4.170	4.169	4.166	2992.	0.678
33.500	0.599	43.23	169.	4.099	4.098	4.095	2981.	0.686
34.000	0.621	44.05	168.	4.027	4.026	4.023	2969.	0.694
34.500	0.643	44.88	168.	3.955	3.954	3.951	2957.	0.702
35.000	0.666	45.70	167.	3.883	3.882	3.879	2946.	0.710
35.500	0.689	46.52	167.	3.811	3.810	3.807	2934.	0.717
36.000	0.712	47.34	167.	3.739	3.738	3.735	2922.	0.724
36.500	0.736	48.16	167.	3.668	3.667	3.664	2910.	0.731
37.000	0.760	48.98	168.	3.597	3.596	3.593	2897.	0.738
37.500	0.785	49.80	168.	3.527	3.525	3.522	2885.	0.744
38.000	0.810	50.63	169.	3.457	3.456	3.453	2873.	0.750
38.500	0.836	51.46	169.	3.388	3.387	3.384	2860.	0.756
39.000	0.861	52.29	170.	3.320	3.319	3.316	2848.	0.762
39.500	0.888	53.12	171.	3.253	3.251	3.248	2835.	0.767
40.000	0.915	53.97	172.	3.186	3.185	3.182	2823.	0.773
40.500	0.942	54.82	174.	3.121	3.119	3.116	2810.	0.778
41.000	0.969	55.67	176.	3.056	3.055	3.052	2798.	0.783
41.500	0.997	56.54	177.	2.993	2.991	2.988	2785.	0.788
42.000	1.026	57.41	179.	2.930	2.929	2.926	2772.	0.792
42.500	1.055	58.30	182.	2.869	2.867	2.864	2760.	0.797
43.000	1.084	59.20	184.	2.808	2.807	2.804	2747.	0.801
43.500	1.114	60.10	187.	2.749	2.748	2.744	2734.	0.806
44.000	1.144	61.03	190.	2.691	2.689	2.686	2721.	0.810
44.500	1.175	61.96	191.	2.633	2.632	2.629	2709.	0.814
44.596	1.181	62.14	190.	2.623	2.621	2.618	2706.	0.814

PROJECTILE EXIT

CONDITIONS AT:	METRIC PMAX	METRIC MUZZLE	ENGLISH PMAX	ENGLISH MUZZLE
TIME (MS):	23.750	44.596		
TRAVEL (M):	0.2571	1.1811		
VELOCITY (M/S)	26.93	62.14		204.
ACCELERATION (G):	160.	190.		
BREECH PRESS (MPA):	5.0317	2.6226	730.	
MEAN PRESS (MPA):	5.0303	2.6210		
BASE PRESS (MPA):	5.0276	2.6178		
MEAN TEMP (K):	3154.	2706.		
Z CHARGE 1 (-):	0.469	0.814		

ENERGY BALANCE SUMMARY	JOULE	%
TOTAL CHEMICAL:	273138.	100.00
(1) INTERNAL GAS:	207424.	75.94
(2) WORK AND LOSSES:	65714.	24.06
(A) PROJECTILE KINETIC:	27151.	9.94
(B) GAS KINETIC:	39.	0.01
(C) PROJECTILE ROTATIONAL:	0.	0.00
(D) FRICTIONAL WORK TO TUBE:	0.	0.00
(E) OTHER FRICTIONAL WORK:	25599.	9.37
(F) WORK DONE AGAINST AIR:	246.	0.09
(G) HEAT CONVECTED TO BORE:	12679.	4.64
(H) RECOIL ENERGY:	0.	0.00

LOADING DENSITY (KG/M3):	18.069
CHARGE WT/PROJECTILE WT:	0.004
PIEZOMETRIC EFFICIENCY:	0.391
EXPANSION RATIO:	5.115

Appendix C. Burst Vent Mode – Canister History (IBHVG2 File 14)

IN THE IGNITER

TIME (MS)	MEAN PRESS MPA	MEAM TEMP K	MDOT IGNI KG/S	G MASS OUT KG	FRAC BURN 1
0.000	0.7218	1252.8	0.000	0.0000	0.0000
0.009	0.8317	1386.6	0.000	0.0000	0.0001
0.123	3.4481	2775.5	0.000	0.0000	0.0021

IGNITER HAS BURST

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Appendix D. Permeable Canister Mode (IBHVG2 Standard Output)

```
 ERRTOL =     0.119209E-06
                               IBHVG2.506d.HILO  DATE:              TIME:

  CARD   1 --> $GUN
  CARD   2 -->      NAME='MORTAR' CHAM=0.0032283 GRVE=0.1219  LAND=0.1219
  CARD   3 -->      TRAV=1.1811  G/L=1.0000  TWST=999.0
  CARD   4 --> $INFO
  CARD   5 -->      DELT=0.12500E-04  DELP=0.50000E-03  INP=2  OUT=2
  CARD   6 -->      POPT=1,1,1,0,1,1  RUN='MORTAR'
  CARD   7 --> $RESI
  CARD   8 -->      NPTS=3  TRAV=0.0,   0.1524,   1.1684
  CARD   9 -->              PRES=0.0,   3.4474,   0.3447
  CARD  10 --> $PROJ
  CARD  11 -->      PRWT=14.0614
  CARD  12 --> $PRIM
  CARD  13 -->      NAME='BPPELLETS'  GAMA=1.2500    FORC=313852.0  COV=0.87789E-03
  CARD  14 -->      TEMP=2380.0       CHWT=0.00010115
  CARD  15 --> $HILO
  CARD  16 -->      IBV=1 NHOL=28 SHOL=.005301 NPRP=1 VOLI=0.00009793
  CARD  17 -->      DCOF=.84 BURP=3.4473  $ SDCF=0.02
  CARD  18 --> $PROP
  CARD  19 -->      NAME='CAN PROP'  RHO=1550.1  GAMA=1.2100   FORC=1169024.1
  CARD  20 -->      COV=0.96532E-03  TEMP=3720.0  CHWT=0.0600   ALPH=0.9035
  CARD  21 -->      BETA=0.0020624   GRAN='BALL'  DIAM=0.0012446    NTBL=0
  CARD  22 --> $END
```

```
 ------------
 - GUN TUBE -
 ------------

 TYPE: MORTAR                    CHAMBER VOLUME (M3) 0.00323   TRAVEL (M):           1.18110
 GROOVE DIAMETER (M):   0.12190  LAND DIAMETER (M):  0.12190   GROOVE/LAND RATIO (-):  1.000
 TWIST (CALS/TURN):     999.0    BORE AREA (M2):     0.01167   HEAT-LOSS OPTION:      1
 SHELL THICKNESS (M):   0.000102  SHELL CP (J/KG-K): 460.3161  SHELL DENSITY (KG/M3): 7861.0913
 INITIAL SHELL TEMP (K): 293.     AIR H0 (W/M**2-K): 11.3482

 --------------
 - PROJECTILE -
 --------------

 TYPE:                           TOTAL WEIGHT (KG):  14.061    WEIGHT PREDICTOR OPTION: 0

 --------------
 - RESISTANCE -
 --------------

 AIR RESISTANCE OPTION:   1   TUBE GAS INITIAL PRES (MPA) 0.000  WALL HEATING FRACTION: 0.000
 RESISTIVE PRESSURE MULT INDEX:  3     RESISTIVE FACTOR   1.000  FRICTION TABLE LENGTH:   3

  I   TRAVEL (M)  PRESSURE (MPA)  I  TRAVEL (M)  PRESSURE (MPA)  I  TRAVEL (M)  PRESSURE (MPA)

  1    0.000          0.000       2     0.152         3.447      3     1.168        0.345

 -----------
 - GENERAL -
 -----------

 MAX TIME STEP (S):  0.000012    PRINT STEP (S):   0.000500  MAX RELATIVE ERROR (-): 0.00200
 PRINT OPTIONS:     1 1 1 0 1 1  STORE OPTION:     0        CONSTANT-PRESSURE OPTION:   0
 GRADIENT MODEL: LAGRANGIAN      INPUT UNITS:  METRIC        OUTPUT UNITS:   METRIC

 ----------
 - RECOIL -
 ----------

 RECOIL OPTION:        0          TYPE:                   RECOILING WEIGHT (KG):  0.

 -----------------------
 - HILO/PRIMER IGNITER -
 -----------------------

 IGNITER HAS  28 HOLES OF    0.0053010 M DIAMETER
 LAST PROPELLANT BURNS IN THE IGNITER
 IGNITER VOLUME IS   0.00009793 M3
 GAS DISCHARGE COEFFICIENT IS  0.8400
   SOLID DISCHARGE COEFFICIENT IS  0.0000
   BURST PRESSURE TO START VENTING OR BURST IS        3.447 MPA
   VENT/BURST SWITCH (1=VENT, 2=BURST) IS 1
```

```
----------
- PRIMER -
----------

TYPE: BPPELLETS                GAMMA (-):        1.2500    FORCE (J/KG):  313852.
COVOLUME (M3/KG):  8.7789E-04  FLAME TEMP (K):   2380.0    WEIGHT (KG):   0.000101

-------------
- CHARGE  1 -
-------------

TYPE: CAN PROP                GRAINS:         38345.  BALL   WEIGHT (KG):        0.0600
EROSIVE COEFF (-):  0.000000  CHARGE IGN CODE:    0          CHARGE IGN AT (S): 0.00000E+00
GRAIN DIAMETER (M): 0.001245

                        PROPERTIES AT LAYER BOUNDARIES OF  LAT SURFACES
                               1ST         2ND         3RD         4TH

  AT DEPTH (M):               ------      ------      ------  0.0000E+00
  ADJACENT LAYER WT %:        ------      ------      ------     100.000
  DENSITY (KG/M3):            ------      ------      ------    1550.100
  GAMMA (-):                  ------      ------      ------      1.2100
  FORCE (J/KG):               ------      ------      ------    1169024.
  COVOLUME (M3/KG):           ------      ------      ------  9.6532E-04
  FLAME TEMP (K):             ------      ------      ------      3720.0
  BURNING RATE EXPS:          ------      ------      ------      0.9035
  BURNING RATE COEFFS:        ------      ------      ------  2.0624E-03
```

```
MORTAR                           IBHVG2.506d.HILO  DATE:            TIME:

  TIME   TRAV    VEL      ACC   BREECH     MEAN     BASE    MEAN  FRAC
  (MS)    (M)    (M/S)    (G)    PRESS    PRESS    PRESS    TEMP  BURN
                                 (MPA)    (MPA)    (MPA)    (K)     1
 0.000  0.000    0.00       9.    0.102    0.102    0.102   293. 0.000
 0.002  0.000    0.00       9.    0.102    0.102    0.102   293. 0.000
LOCAL PRESSURE MAX DETECTED
BARREL RESISTANCE OVERCOME - PROJECTILE MOVING
 0.123  0.000    0.01       9.    0.102    0.102    0.102   293. 0.002
LOCAL PRESSURE MIN DETECTED
IGNITER IS STARTING TO VENT
 0.500  0.000    0.10      48.    0.571    0.571    0.571  1274. 0.029
 1.000  0.000    0.66     205.    2.424    2.423    2.423  2701. 0.133
 1.500  0.001    2.30     478.    5.665    5.664    5.663  3236. 0.301
 2.000  0.003    5.36     761.    9.068    9.065    9.060  3406. 0.455
 2.500  0.006    9.63     960.   11.507   11.503   11.495  3464. 0.558
 3.000  0.012   14.62    1061.   12.843   12.838   12.827  3479. 0.619
 3.500  0.021   19.91    1084.   13.315   13.309   13.298  3471. 0.656
 3.670  0.025   21.71    1079.   13.335   13.329   13.317  3465. 0.666
LOCAL PRESSURE MAX DETECTED
 4.000  0.032   25.17    1060.   13.286   13.280   13.268  3451. 0.684
 4.500  0.046   30.27    1015.   13.069   13.063   13.051  3424. 0.710
 5.000  0.063   35.10     954.   12.717   12.712   12.700  3394. 0.733
 5.500  0.081   39.60     880.   12.267   12.261   12.250  3360. 0.755
 6.000  0.102   43.71     796.   11.749   11.744   11.734  3323. 0.774
 6.500  0.125   47.39     705.   11.195   11.190   11.181  3285. 0.792
 7.000  0.149   50.62     610.   10.627   10.623   10.615  3247. 0.807
 7.500  0.175   53.48     563.   10.065   10.062   10.054  3208. 0.821
 8.000  0.203   56.15     524.    9.518    9.514    9.507  3170. 0.834
 8.500  0.232   58.62     487.    8.993    8.990    8.983  3132. 0.846
 9.000  0.261   60.93     452.    8.493    8.490    8.483  3095. 0.856
 9.500  0.292   63.06     420.    8.021    8.018    8.012  3059. 0.865
10.000  0.325   65.05     391.    7.577    7.574    7.568  3023. 0.874
10.500  0.357   66.90     364.    7.162    7.159    7.154  2989. 0.882
11.000  0.391   68.62     340.    6.774    6.771    6.766  2955. 0.889
11.500  0.426   70.24     318.    6.413    6.410    6.406  2922. 0.895
12.000  0.462   71.75     299.    6.076    6.074    6.069  2890. 0.901
12.500  0.498   73.17     282.    5.763    5.761    5.757  2859. 0.906
13.000  0.535   74.52     267.    5.471    5.469    5.465  2829. 0.911
13.500  0.572   75.79     253.    5.200    5.198    5.194  2800. 0.916
14.000  0.611   77.00     242.    4.947    4.945    4.942  2771. 0.920
14.500  0.649   78.16     232.    4.712    4.710    4.706  2744. 0.924
15.000  0.689   79.28     223.    4.492    4.490    4.487  2717. 0.927
15.500  0.729   80.36     216.    4.287    4.285    4.282  2690. 0.930
16.000  0.769   81.40     210.    4.095    4.093    4.090  2665. 0.934
16.500  0.810   82.42     206.    3.915    3.913    3.910  2639. 0.936
17.000  0.852   83.42     202.    3.746    3.745    3.741  2615. 0.939
17.500  0.893   84.41     200.    3.588    3.587    3.584  2591. 0.942
18.000  0.936   85.38     198.    3.440    3.438    3.435  2568. 0.944
18.500  0.979   86.35     197.    3.300    3.298    3.295  2545. 0.946
19.000  1.022   87.32     197.    3.168    3.167    3.164  2523. 0.948
19.500  1.066   88.29     198.    3.044    3.043    3.039  2501. 0.950
20.000  1.111   89.27     200.    2.927    2.925    2.922  2479. 0.952
20.500  1.156   90.25     202.    2.816    2.814    2.811  2458. 0.954
20.783  1.181   90.81     200.    2.756    2.754    2.751  2447. 0.955
PROJECTILE EXIT
```

CONDITIONS AT:	METRIC PMAX	METRIC MUZZLE	ENGLISH PMAX	ENGLISH MUZZLE
TIME (MS):	3.670	20.783		
TRAVEL (M):	0.0246	1.1811		
VELOCITY (M/S)	21.71	90.81		298.
ACCELERATION (G):	1079.	200.		
BREECH PRESS (MPA):	13.3345	2.7561	1934.	
MEAN PRESS (MPA):	13.3286	2.7545		
BASE PRESS (MPA):	13.3169	2.7513		
MEAN TEMP (K):	3465.	2447.		
Z CHARGE 1 (-):	0.666	0.955		

ENERGY BALANCE SUMMARY	JOULE	%
TOTAL CHEMICAL:	318684.	100.00
(1) INTERNAL GAS:	217487.	68.25
(2) WORK AND LOSSES:	101196.	31.75
(A) PROJECTILE KINETIC:	57977.	18.19
(B) GAS KINETIC:	79.	0.02
(C) PROJECTILE ROTATIONAL:	0.	0.00
(D) FRICTIONAL WORK TO TUBE:	0.	0.00
(E) OTHER FRICTIONAL WORK:	25599.	8.03
(F) WORK DONE AGAINST AIR:	456.	0.14
(G) HEAT CONVECTED TO BORE:	17085.	5.36
(H) RECOIL ENERGY:	0.	0.00

LOADING DENSITY (KG/M3):	17.723
CHARGE WT/PROJECTILE WT:	0.004
PIEZOMETRIC EFFICIENCY:	0.315
EXPANSION RATIO:	5.270

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Appendix E. Permeable Canister Mode – Canister History (IBHVG2 File 14)

IN THE IGNITER

TIME (MS)	MEAN PRESS MPA	MEAM TEMP K	MDOT IGNI KG/S	G MASS OUT KG	FRAC BURN 1
0.000	0.7218	1252.8	0.000	0.0000	0.0000
0.002	0.7408	1276.8	0.000	0.0000	0.0000
0.123	3.4479	2775.5	0.000	0.0000	0.0021
IGNITER IS STARTING TO VENT					
0.500	16.3516	3690.5	4.892	0.0011	0.0290
1.000	47.0276	3719.4	13.944	0.0057	0.1333
1.500	66.2408	3720.0	19.638	0.0144	0.3009
2.000	57.5616	3720.0	17.065	0.0239	0.4550
2.500	39.1598	3720.0	11.609	0.0310	0.5580
3.000	24.1322	3720.0	7.154	0.0357	0.6194
3.500	16.0727	3720.0	3.957	0.0384	0.6559
3.670	15.4874	3720.0	3.529	0.0390	0.6658
4.000	15.1024	3720.0	3.252	0.0401	0.6840
4.500	14.6362	3720.0	3.006	0.0417	0.7097
5.000	14.0708	3720.0	2.763	0.0431	0.7333
5.500	13.4325	3720.0	2.525	0.0444	0.7547
6.000	12.7510	3720.0	2.295	0.0457	0.7740
6.500	12.0559	3720.0	2.080	0.0467	0.7915
7.000	11.3669	3720.0	1.882	0.0477	0.8072
7.500	10.7016	3720.0	1.701	0.0486	0.8214
8.000	10.0664	3720.0	1.538	0.0494	0.8341
8.500	9.4671	3720.0	1.392	0.0502	0.8456
9.000	8.9038	3720.0	1.261	0.0508	0.8560
9.500	8.3785	3720.0	1.144	0.0514	0.8653
10.000	7.8891	3720.0	1.040	0.0520	0.8738
10.500	7.4353	3720.0	0.947	0.0525	0.8815
11.000	7.0140	3720.0	0.864	0.0529	0.8886
11.500	6.6244	3720.0	0.790	0.0533	0.8949
12.000	6.2632	3720.0	0.724	0.0537	0.9008
12.500	5.9291	3720.0	0.665	0.0541	0.9061
13.000	5.6192	3720.0	0.611	0.0544	0.9111
13.500	5.3322	3720.0	0.564	0.0547	0.9156
14.000	5.0654	3720.0	0.521	0.0549	0.9198
14.500	4.8179	3720.0	0.482	0.0552	0.9236
15.000	4.5873	3720.0	0.447	0.0554	0.9272
15.500	4.3729	3720.0	0.415	0.0556	0.9305
16.000	4.1726	3720.0	0.386	0.0558	0.9336
16.500	3.9855	3720.0	0.360	0.0560	0.9364
17.000	3.8105	3720.0	0.336	0.0562	0.9391
17.500	3.6468	3720.0	0.314	0.0564	0.9416
18.000	3.4931	3720.0	0.294	0.0565	0.9439
18.500	3.3487	3720.0	0.276	0.0567	0.9461
19.000	3.2129	3720.0	0.259	0.0568	0.9481
19.500	3.0852	3720.0	0.244	0.0569	0.9501
20.000	2.9646	3720.0	0.229	0.0570	0.9519
20.500	2.8507	3720.0	0.216	0.0572	0.9536
20.783	2.7891	3720.0	0.209	0.0572	0.9545

INTENTIONALLY LEFT BLANK

Appendix F. Permeable Canister Mode With Solid Particle Discharge (IBHVG2 File 9)

```
 ERRTOL =    0.119209E-06
                                              IBHVG2.506d.HILO  DATE:              TIME:

  CARD   1 --> $GUN
  CARD   2 -->      NAME='MORTAR' CHAM=0.0032283 GRVE=0.1219  LAND=0.1219
  CARD   3 -->      TRAV=1.1811  G/L=1.0000  TWST=999.0
  CARD   4 --> $INFO
  CARD   5 -->      DELT=0.12500E-04  DELP=0.50000E-03  INP=2  OUT=2
  CARD   6 -->      POPT=1,1,1,0,1,1  RUN='MORTAR'
  CARD   7 --> $RESI
  CARD   8 -->      NPTS=3  TRAV=0.0,   0.1524,   1.1684
  CARD   9 -->              PRES=0.0,   3.4474,   0.3447
  CARD  10 --> $PROJ
  CARD  11 -->      PRWT=14.0614
  CARD  12 --> $PRIM
  CARD  13 -->      NAME='BPPELLETS'  GAMA=1.2500    FORC=313852.0  COV=0.87789E-03
  CARD  14 -->      TEMP=2380.0       CHWT=0.00010115
  CARD  15 --> $HILO
  CARD  16 -->      IBV=1 NHOL=28 SHOL=.005301 NPRP=1 VOLI=0.00009793
  CARD  17 -->      DCOF=.84 BURP=3.4473 SDCF=0.02
  CARD  18 --> $PROP
  CARD  19 -->      NAME='CAN PROP'  RHO=1550.1  GAMA=1.2100   FORC=1169024.1
  CARD  20 -->      COV=0.96532E-03  TEMP=3720.0  CHWT=0.0600   ALPH=0.9035
  CARD  21 -->      BETA=0.0020624   GRAN='BALL'  DIAM=0.0012446    NTBL=0
  CARD  22 --> $END
```

```
MORTAR                         IBHVG2.506d.HILO  DATE:            TIME:


------------
- GUN TUBE -
------------

TYPE: MORTAR                   CHAMBER VOLUME (M3): 0.00323  TRAVEL (M):            1.18110
GROOVE DIAMETER (M):  0.12190  LAND DIAMETER (M):   0.12190  GROOVE/LAND RATIO (-): 1.000
TWIST (CALS/TURN):    999.0    BORE AREA (M2):      0.01167  HEAT-LOSS OPTION:      1
SHELL THICKNESS (M):  0.000102  SHELL CP (J/KG-K):  460.3161 SHELL DENSITY (KG/M3): 7861.0913
INITIAL SHELL TEMP (K): 293.   AIR H0 (W/M**2-K):   11.3482

--------------
- PROJECTILE -
--------------

TYPE:                        TOTAL WEIGHT (KG):     14.061    WEIGHT PREDICTOR OPTION:  0

--------------
- RESISTANCE -
--------------

AIR RESISTANCE OPTION:  1      TUBE GAS INITIAL PRES (MPA) 0.000  WALL HEATING FRACTION: 0.000
RESISTIVE PRESSURE MULT INDEX: 3     RESISTIVE FACTOR      1.000  FRICTION TABLE LENGTH: 3

 I  TRAVEL (M)  PRESSURE (MPA)  I  TRAVEL (M)  PRESSURE (MPA)  I  TRAVEL (M)  PRESSURE (MPA)

 1     0.000         0.000      2     0.152         3.447      3     1.168         0.345

-----------
- GENERAL -
-----------

MAX TIME STEP (S):    0.000012  PRINT STEP (S):  0.000500  MAX RELATIVE ERROR (-): 0.00200
PRINT OPTIONS:     1 1 1 0 1 1  STORE OPTION:    0         CONSTANT-PRESSURE OPTION: 0
GRADIENT MODEL: LAGRANGIAN      INPUT UNITS:     METRIC    OUTPUT UNITS:           METRIC

----------
- RECOIL -
----------

RECOIL OPTION:           0        TYPE:                  RECOILING WEIGHT (KG):  0.

-----------------------
- HILO/PRIMER IGNITER -
-----------------------

  IGNITER HAS  28 HOLES OF    0.0053010 M DIAMETER
  LAST PROPELLANT BURNS IN THE IGNITER
  IGNITER VOLUME IS   0.00009793 M3
  GAS DISCHARGE COEFFICIENT IS  0.8400
  SOLID DISCHARGE COEFFICIENT IS  0.0200
  BURST PRESSURE TO START VENTING OR BURST IS        3.447 MPA
  VENT/BURST SWITCH (1=VENT, 2=BURST) IS 1
```

```
----------
- PRIMER -
----------

TYPE: BPPELLETS              GAMMA (-):       1.2500   FORCE (J/KG):    313852.
COVOLUME (M3/KG): 8.7789E-04  FLAME TEMP (K):  2380.0   WEIGHT (KG):     0.000101

-------------
- CHARGE  1 -
-------------

TYPE: CAN PROP               GRAINS:        0.00000E+00 BALL  WEIGHT (KG):     0.0000
EROSIVE COEFF (-):  0.000000  CHARGE IGN CODE:      1          CHARGE IGN AT (S): 0.10000E+02
GRAIN DIAMETER (M): 0.000100

                       PROPERTIES AT LAYER BOUNDARIES OF  LAT SURFACES
                             1ST         2ND         3RD         4TH

  AT DEPTH (M):             ------      ------      ------  0.0000E+00
  ADJACENT LAYER WT %:      ------      ------      ------     100.000
  DENSITY (KG/M3):          ------      ------      ------    1550.100
  GAMMA (-):                ------      ------      ------      1.2100
  FORCE (J/KG):             ------      ------      ------    1169024.
  COVOLUME (M3/KG):         ------      ------      ------  9.6532E-04
  FLAME TEMP (K):           ------      ------      ------      3720.0
  BURNING RATE EXPS:        ------      ------      ------      0.9035
  BURNING RATE COEFFS:      ------      ------      ------  2.0624E-03

-------------
- CHARGE  2 -
-------------

TYPE: CAN PROP              GRAINS:         38345.   BALL   WEIGHT (KG):       0.0600
EROSIVE COEFF (-): 0.000000  CHARGE IGN CODE:         0      CHARGE IGN AT (S): 0.00000E+00
GRAIN DIAMETER (M):  0.001245

                       PROPERTIES AT LAYER BOUNDARIES OF  LAT SURFACES
                             1ST         2ND         3RD         4TH

  AT DEPTH (M):             ------      ------      ------  0.0000E+00
  ADJACENT LAYER WT %:      ------      ------      ------     100.000
  DENSITY (KG/M3):          ------      ------      ------    1550.100
  GAMMA (-):                ------      ------      ------      1.2100
  FORCE (J/KG):             ------      ------      ------    1169024.
  COVOLUME (M3/KG):         ------      ------      ------  9.6532E-04
  FLAME TEMP (K):           ------      ------      ------      3720.0
  BURNING RATE EXPS:        ------      ------      ------      0.9035
  BURNING RATE COEFFS:      ------      ------      ------  2.0624E-03
```

```
  TIME    TRAV     VEL      ACC    BREECH      MEAN     BASE     MEAN  FRAC  FRAC
  (MS)     (M)    (M/S)     (G)     PRESS     PRESS    PRESS     TEMP  BURN  BURN
                                    (MPA)     (MPA)    (MPA)     (K)    1     2
 0.000  0.000    0.00        9.     0.102     0.102    0.102    293. 0.000 0.000
 0.002  0.000    0.00        9.     0.102     0.102    0.102    293. 0.000 0.000
LOCAL PRESSURE MAX DETECTED
BARREL RESISTANCE OVERCOME - PROJECTILE MOVING
 0.123  0.000    0.01        9.     0.102     0.102    0.102    293. 0.000 0.002
LOCAL PRESSURE MIN DETECTED
IGNITER IS STARTING TO VENT
 0.500  0.000    0.10       47.     0.551     0.551    0.551   1241. 0.001 0.066
PROPELLANT  1 IGNITED
 1.000  0.000    0.61      175.     2.074     2.074    2.073   2566. 0.005 0.195
 1.500  0.001    1.91      362.     4.302     4.302    4.301   3097. 0.016 0.340
 2.000  0.002    4.15      542.     6.458     6.457    6.454   3290. 0.034 0.459
 2.500  0.005    7.14      670.     8.036     8.034    8.030   3366. 0.059 0.542
 3.000  0.009   10.62      743.     9.004     9.002    8.997   3396. 0.087 0.597
 3.500  0.016   14.35      770.     9.471     9.468    9.463   3401. 0.118 0.634
 4.000  0.024   18.14      774.     9.705     9.702    9.696   3396. 0.149 0.663
 4.500  0.034   21.92      766.     9.832     9.829    9.823   3386. 0.181 0.690
 4.905  0.043   24.94      750.     9.863     9.860    9.854   3374. 0.207 0.709
LOCAL PRESSURE MAX DETECTED
 5.000  0.046   25.63      745.     9.861     9.858    9.852   3371. 0.213 0.714
 5.500  0.059   29.21      714.     9.803     9.800    9.794   3352. 0.244 0.736
 6.000  0.075   32.62      673.     9.670     9.667    9.661   3330. 0.274 0.756
 6.500  0.092   35.80      624.     9.476     9.473    9.468   3306. 0.303 0.774
 7.000  0.111   38.73      568.     9.236     9.233    9.228   3280. 0.330 0.791
 7.500  0.131   41.36      506.     8.963     8.961    8.956   3253. 0.357 0.805
 8.000  0.152   43.68      441.     8.670     8.668    8.664   3226. 0.383 0.819
 8.500  0.174   45.79      420.     8.366     8.365    8.361   3198. 0.407 0.831
 9.000  0.198   47.80      400.     8.058     8.056    8.052   3170. 0.430 0.843
 9.500  0.222   49.71      380.     7.750     7.748    7.745   3142. 0.451 0.853
10.000  0.247   51.53      361.     7.445     7.444    7.440   3114. 0.472 0.862
10.500  0.274   53.25      342.     7.148     7.146    7.143   3087. 0.491 0.871
11.000  0.301   54.88      324.     6.858     6.856    6.853   3060. 0.510 0.878
11.500  0.328   56.43      308.     6.578     6.576    6.573   3033. 0.527 0.885
12.000  0.357   57.90      292.     6.308     6.307    6.304   3007. 0.543 0.892
12.500  0.386   59.30      278.     6.051     6.049    6.046   2981. 0.559 0.898
13.000  0.416   60.63      265.     5.804     5.802    5.800   2956. 0.574 0.903
13.500  0.447   61.90      253.     5.569     5.567    5.565   2931. 0.588 0.908
14.000  0.478   63.11      242.     5.344     5.343    5.340   2907. 0.601 0.913
14.500  0.510   64.27      232.     5.131     5.130    5.128   2883. 0.613 0.917
15.000  0.543   65.39      223.     4.929     4.928    4.925   2859. 0.625 0.921
15.500  0.575   66.47      216.     4.737     4.735    4.733   2836. 0.636 0.925
16.000  0.609   67.51      209.     4.554     4.553    4.550   2813. 0.647 0.929
16.500  0.643   68.52      203.     4.380     4.379    4.377   2791. 0.657 0.932
17.000  0.678   69.50      198.     4.216     4.215    4.212   2770. 0.667 0.935
17.500  0.712   70.46      194.     4.059     4.058    4.056   2748. 0.676 0.938
18.000  0.748   71.40      190.     3.911     3.910    3.908   2727. 0.684 0.940
18.500  0.784   72.32      187.     3.769     3.768    3.766   2707. 0.693 0.943
19.000  0.820   73.24      185.     3.635     3.634    3.632   2686. 0.701 0.945
19.500  0.857   74.14      184.     3.507     3.506    3.504   2667. 0.708 0.947
20.000  0.894   75.04      183.     3.386     3.385    3.383   2647. 0.715 0.949
20.500  0.932   75.94      183.     3.270     3.269    3.267   2628. 0.722 0.951
21.000  0.970   76.84      184.     3.159     3.158    3.156   2609. 0.729 0.953
21.500  1.009   77.75      185.     3.054     3.053    3.051   2590. 0.735 0.955
22.000  1.048   78.66      186.     2.953     2.952    2.950   2572. 0.741 0.956
22.500  1.088   79.58      188.     2.857     2.856    2.854   2554. 0.747 0.958
23.000  1.128   80.51      191.     2.765     2.764    2.762   2536. 0.753 0.959
23.500  1.168   81.45      194.     2.677     2.676    2.674   2518. 0.758 0.961
23.656  1.181   81.74      192.     2.650     2.649    2.647   2513. 0.760 0.961
```

IN THE IGNITER

TIME (MS)	MEAN PRESS MPA	MEAM TEMP K	MDOT IGNI KG/S	G MASS OUT KG	FRAC BURN 1	SLD EXIT 1
0.000	0.7218	1252.8	0.000	0.0000	0.0000	0.0000
0.002	0.7408	1276.8	0.000	0.0000	0.0000	0.0000
0.123	3.4479	2775.5	0.000	0.0000	0.0021	0.0000
IGNITER IS STARTING TO VENT						
0.500	14.9028	3687.6	4.462	0.0010	0.0661	0.0023
1.000	34.4578	3719.2	10.218	0.0047	0.1946	0.0052
1.500	41.6062	3719.9	12.335	0.0106	0.3396	0.0075
2.000	34.3417	3720.0	10.181	0.0163	0.4591	0.0092
2.500	23.2681	3720.0	6.898	0.0206	0.5420	0.0105
3.000	14.3164	3720.0	4.248	0.0233	0.5969	0.0116
3.500	10.8818	3720.0	2.412	0.0249	0.6335	0.0125
4.000	10.8247	3720.0	2.190	0.0260	0.6629	0.0131
4.500	10.8052	3720.0	2.062	0.0271	0.6896	0.0137
4.905	10.7337	3720.0	1.958	0.0279	0.7094	0.0140
5.000	10.7100	3720.0	1.934	0.0281	0.7138	0.0141
5.500	10.5435	3720.0	1.805	0.0290	0.7358	0.0145
6.000	10.3158	3720.0	1.678	0.0299	0.7559	0.0148
6.500	10.0399	3720.0	1.554	0.0307	0.7740	0.0151
7.000	9.7280	3720.0	1.436	0.0315	0.7905	0.0154
7.500	9.3931	3720.0	1.323	0.0322	0.8055	0.0156
8.000	9.0456	3720.0	1.218	0.0328	0.8190	0.0158
8.500	8.6950	3720.0	1.120	0.0334	0.8314	0.0160
9.000	8.3459	3720.0	1.030	0.0339	0.8426	0.0162
9.500	8.0030	3720.0	0.947	0.0344	0.8527	0.0163
10.000	7.6679	3720.0	0.872	0.0349	0.8620	0.0164
10.500	7.3438	3720.0	0.803	0.0353	0.8705	0.0165
11.000	7.0311	3720.0	0.740	0.0357	0.8783	0.0166
11.500	6.7316	3720.0	0.683	0.0360	0.8853	0.0167
12.000	6.4449	3720.0	0.630	0.0363	0.8919	0.0168
12.500	6.1720	3720.0	0.583	0.0367	0.8978	0.0169
13.000	5.9120	3720.0	0.540	0.0369	0.9033	0.0170
13.500	5.6654	3720.0	0.500	0.0372	0.9084	0.0170
14.000	5.4312	3720.0	0.464	0.0374	0.9131	0.0171
14.500	5.2094	3720.0	0.432	0.0377	0.9174	0.0171
15.000	4.9990	3720.0	0.402	0.0379	0.9214	0.0172
15.500	4.8000	3720.0	0.374	0.0381	0.9252	0.0172
16.000	4.6111	3720.0	0.349	0.0382	0.9286	0.0173
16.500	4.4323	3720.0	0.326	0.0384	0.9318	0.0173
17.000	4.2627	3720.0	0.305	0.0386	0.9348	0.0174
17.500	4.1022	3720.0	0.286	0.0387	0.9376	0.0174
18.000	3.9497	3720.0	0.268	0.0389	0.9403	0.0174
18.500	3.8050	3720.0	0.252	0.0390	0.9427	0.0174
19.000	3.6676	3720.0	0.237	0.0391	0.9450	0.0175
19.500	3.5372	3720.0	0.223	0.0392	0.9472	0.0175
20.000	3.4130	3720.0	0.210	0.0393	0.9492	0.0175
20.500	3.2948	3720.0	0.198	0.0394	0.9511	0.0175
21.000	3.1822	3720.0	0.187	0.0395	0.9529	0.0176
21.500	3.0750	3720.0	0.176	0.0396	0.9546	0.0176
22.000	2.9726	3720.0	0.167	0.0397	0.9562	0.0176
22.500	2.8749	3720.0	0.158	0.0398	0.9577	0.0176
23.000	2.7815	3720.0	0.150	0.0399	0.9592	0.0176
23.500	2.6923	3720.0	0.142	0.0399	0.9605	0.0177
23.656	2.6652	3720.0	0.140	0.0400	0.9609	0.0177

PROJECTILE EXIT

CONDITIONS AT:	METRIC PMAX	METRIC MUZZLE	ENGLISH PMAX	ENGLISH MUZZLE
TIME (MS):	4.905	23.656		
TRAVEL (M):	0.0433	1.1811		
VELOCITY (M/S)	24.94	81.74		268.
ACCELERATION (G):	750.	192.		
BREECH PRESS (MPA):	9.8627	2.6503	1430.	
MEAN PRESS (MPA):	9.8598	2.6492		
BASE PRESS (MPA):	9.8539	2.6470		
MEAN TEMP (K):	3374.	2513.		
Z CHARGE 1 (-):	0.207	0.760		
Z CHARGE 2 (-):	0.709	0.961		

ENERGY BALANCE SUMMARY	JOULE	%
TOTAL CHEMICAL:	297250.	100.00
(1) INTERNAL GAS:	208869.	70.27
(2) WORK AND LOSSES:	88381.	29.73
(A) PROJECTILE KINETIC:	46980.	15.80
(B) GAS KINETIC:	44.	0.01
(C) PROJECTILE ROTATIONAL:	0.	0.00
(D) FRICTIONAL WORK TO TUBE:	0.	0.00
(E) OTHER FRICTIONAL WORK:	25599.	8.61
(F) WORK DONE AGAINST AIR:	395.	0.13
(G) HEAT CONVECTED TO BORE:	15362.	5.17
(H) RECOIL ENERGY:	0.	0.00

LOADING DENSITY (KG/M3):	12.376
CHARGE WT/PROJECTILE WT:	0.003
PIEZOMETRIC EFFICIENCY:	0.346
EXPANSION RATIO:	5.270

Appendix G. Standard IBHVG2 Computation With Added Main Charge

```
ERRTOL =    0.119209E-06


                                IBHVG2.506d.HILO  DATE:              TIME:

0 CARD   1 --> $GUN
  CARD   2 -->      NAME     = 'MORTAR'                        CHAM     = 0.0032283
  CARD   3 -->      GRVE     =    0.1219                       LAND     =    0.1219
  CARD   4 -->      TRAV     =    1.1811                       G/L      =    1.0000
  CARD   5 -->      TWST     =     999.0
  CARD   6 --> $INFO
  CARD   7 -->      DELT     =  0.12500E-04                    DELP     =  0.10000E-03
  CARD   8 -->      INP      =  0                              OUT      =  0
  CARD   9 -->      POPT     =  1, 1, 1, 0, 0, 1
  CARD  10 -->      RUN      = 'MORTAR W/ MAIN CHG'
  CARD  11 --> $RESI
  CARD  12 -->      NPTS     =  3                              TRAV     = 0.0,   0.1524,   1.1684
  CARD  13 -->      PRES     = 0.0,   3.4474,   0.3447
  CARD  14 --> $PROJ
  CARD  15 -->      PRWT     =   14.0614
  CARD  16 --> $PRIM
  CARD  17 -->      NAME     = 'BPPELLETS'                     GAMA     =    1.2500
  CARD  18 -->      FORC     =  313852.0                       COV      =  0.87789E-03
  CARD  19 -->      TEMP     =    2380.0                       CHWT     =  0.10115E-02
  CARD  20 --> $PROP
  CARD  21 -->      NAME     = 'MAIN CHG'                      NTBL     = -1
  CARD  22 -->      DEPL     = 0.0,0.0, 0.17424E-03            EX1L     =    0.7900
  CARD  23 -->      EX2L     =    0.7900                       EX3L     =    0.7900
  CARD  24 -->      EX4L     =    0.8900                       CF1L     = 0.0013602
  CARD  25 -->      CF2L     = 0.0013602                       CF3L     = 0.0013602
  CARD  26 -->      CF4L     = 0.0022374                 RHOL     =  1550.1, 1550.1, 1550.1, 1550.1
  CARD  27 -->      GAML     =    1.2600,   1.2600,   1.2600,   1.2200
  CARD  28 -->      FRCL     =  866829.4, 866829.4, 866829.4,1105954.9
  CARD  29 -->      COVL     = 0.0011199,0.0011199,0.0011199, 0.99350E-03
  CARD  30 -->      TMPL     =    2070.0,   2070.0,   2070.0,   3350.0
  CARD  31 -->      GRAN     = 'CAKE'                          WRED     =    0.3000
  CARD  32 -->      ORGD     =  0.71120E-03                    CHWT     =    0.2300
  CARD  33 --> $COMM HILO
  CARD  34 -->      IBV      =  1                              NHOL     = 28
  CARD  35 -->      SHOL     = 0.0053010                       NPRP     =  1
  CARD  36 -->      VOLI     =  0.97929E-04                    DCOF     =    0.8400
  CARD  37 -->      BURP     =    3.4474                       SDCF     =    0.0200
  CARD  38 --> $PROP
  CARD  39 -->      NAME     = 'CAN PROP'                      RHO      =    1550.1
  CARD  40 -->      GAMA     =    1.2100                       FORC     = 1169024.1
  CARD  41 -->      COV      =  0.96532E-03                    TEMP     =    3720.0
  CARD  42 -->      CHWT     =    0.0600                       ALPH     =    0.9035
  CARD  43 -->      BETA     = 0.0020624                       GRAN     = 'BALL'
  CARD  44 -->      DIAM     = 0.0012446                       NTBL     =  0
  CARD  45 --> $END
```

```
MORTAR W/ MAIN CHG               IBHVG2.506d.HILO  DATE:            TIME:


------------
- GUN TUBE -
------------

TYPE: MORTAR                    CHAMBER VOLUME (M3):  0.00323  TRAVEL (M):          1.18110
GROOVE DIAMETER (M):  0.12190   LAND DIAMETER (M):    0.12190  GROOVE/LAND RATIO (-): 1.000
TWIST (CALS/TURN):      999.0   BORE AREA (M2):       0.01167  HEAT-LOSS OPTION:      1
SHELL THICKNESS (M): 0.000102   SHELL CP (J/KG-K):   460.3161  SHELL DENSITY (KG/M3): 7861.0913
INITIAL SHELL TEMP (K):  293.   AIR H0 (W/M**2-K):    11.3482

--------------
- PROJECTILE -
--------------

TYPE:                           TOTAL WEIGHT (KG):    14.061    WEIGHT PREDICTOR OPTION: 0

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- RESISTANCE -
--------------

AIR RESISTANCE OPTION:      1  TUBE GAS INITIAL PRES (MPA) 0.000  WALL HEATING FRACTION: 0.000
RESISTIVE PRESSURE MULT INDEX: 3  RESISTIVE FACTOR        1.000  FRICTION TABLE LENGTH: 3

I  TRAVEL (M)  PRESSURE (MPA)  I  TRAVEL (M)  PRESSURE (MPA)  I  TRAVEL (M)  PRESSURE (MPA)

1   0.000        0.000         2   0.152           3.447      3   1.168           0.345

-----------
- GENERAL -
-----------

MAX TIME STEP (S):     0.000012    PRINT STEP (S):  0.000100  MAX RELATIVE ERROR (-): 0.00200
PRINT OPTIONS:      1 1 1 0 0 1    STORE OPTION:      0       CONSTANT-PRESSURE OPTION:     0
GRADIENT MODEL: LAGRANGIAN         INPUT UNITS:   METRIC      OUTPUT UNITS:   METRIC

----------
- RECOIL -
----------

RECOIL OPTION:                 0    TYPE:                     RECOILING WEIGHT (KG):  0.

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- PRIMER -
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TYPE: BPPELLETS                  GAMMA (-):       1.250     FORCE (J/KG):  313852.
COVOLUME (M3/KG):  8.7789E-04    FLAME TEMP (K):  2380.0    WEIGHT (KG):  0.001012

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- CHARGE  1 -
-------------

TYPE: MAIN CHG                 GRAINS:         0.78776E+06 CAKE  WEIGHT (KG):       0.2300
EROSIVE COEFF (-): 0.000000    CHARGE IGN CODE:          0      CHARGE IGN AT (S): 0.00000E+00
ORIG DIA (M): 0.7112E-03  %WEB REDUCT. : 0.30  THICKNESS (M): 0.4978E-03  DIAMETER (M): 0.7919E-03
```

PROPERTIES AT LAYER BOUNDARIES OF LAT SURFACES	1ST	2ND	3RD	4TH
AT DEPTH (M):	------	------	0.0000E+00	1.7424E-04
ADJACENT LAYER WT %:	------	------	89.389	10.611
DENSITY (KG/M3):	------	------	1550.100	1550.100
GAMMA (-):	------	------	1.2600	1.2200
FORCE (J/KG):	------	------	866829.	1105955.
COVOLUME (M3/KG):	------	------	1.1199E-03	9.9350E-04
FLAME TEMP (K):	------	------	2070.0	3350.0
MEAN PRESSURES (MPA):	------	------	0.000	0.000
BURNING RATE EXPS:	------	------	0.7900	0.8900
BURNING RATE COEFFS:	------	------	1.3602E-03	2.2374E-03

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- CHARGE  2 -
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TYPE: CAN PROP                  GRAINS:         38345.  BALL  WEIGHT (KG):          0.0600
EROSIVE COEFF (-):  0.000000    CHARGE IGN CODE:      0       CHARGE IGN AT (S): 0.00000E+00
GRAIN DIAMETER (M):  0.001245
```

PROPERTIES AT LAYER BOUNDARIES OF LAT SURFACES	1ST	2ND	3RD	4TH
AT DEPTH (M):	------	------	------	0.0000E+00
ADJACENT LAYER WT %:	------	------	------	100.000
DENSITY (KG/M3):	------	------	------	1550.100
GAMMA (-):	------	------	------	1.2100
FORCE (J/KG):	------	------	------	1169024.
COVOLUME (M3/KG):	------	------	------	9.6532E-04
FLAME TEMP (K):	------	------	------	3720.0
BURNING RATE EXPS:	------	------	------	0.9035
BURNING RATE COEFFS:	------	------	------	2.0624E-03

MORTAR W/ MAIN CHG IBHVG2.506d.HILO DATE: TIME:

TIME (MS)	TRAV (M)	VEL (M/S)	ACC (G)	BREECH PRESS (MPA)	MEAN PRESS (MPA)	BASE PRESS (MPA)	MEAN TEMP (K)	FRAC BURN 1	FRAC BURN 2
0 0.000	0.000	0.00	9.	0.105	0.104	0.104	2380.	0.000	0.000
0.100	0.000	0.01	10.	0.122	0.122	0.121	2367.	0.000	0.000
BARREL RESISTANCE OVERCOME - PROJECTILE MOVING									
0.200	0.000	0.02	12.	0.142	0.141	0.140	2358.	0.000	0.000
0.300	0.000	0.03	14.	0.164	0.163	0.162	2350.	0.001	0.000
0.400	0.000	0.05	16.	0.189	0.188	0.187	2344.	0.001	0.001
0.500	0.000	0.06	18.	0.217	0.216	0.214	2339.	0.001	0.001
0.600	0.000	0.08	21.	0.248	0.247	0.245	2336.	0.002	0.001
0.700	0.000	0.10	24.	0.282	0.281	0.279	2333.	0.002	0.001
0.800	0.000	0.13	27.	0.321	0.320	0.317	2332.	0.003	0.002
0.900	0.000	0.16	30.	0.363	0.362	0.360	2331.	0.003	0.002
1.000	0.000	0.19	34.	0.410	0.409	0.406	2330.	0.004	0.003
1.100	0.000	0.22	39.	0.462	0.461	0.458	2330.	0.004	0.003
1.200	0.000	0.26	43.	0.520	0.518	0.514	2330.	0.005	0.004
1.300	0.000	0.31	48.	0.582	0.580	0.576	2331.	0.006	0.004
1.400	0.000	0.36	54.	0.651	0.649	0.645	2332.	0.006	0.005
1.500	0.000	0.42	60.	0.726	0.724	0.719	2333.	0.007	0.006
1.600	0.000	0.48	67.	0.809	0.806	0.800	2334.	0.008	0.006
1.700	0.000	0.55	75.	0.898	0.895	0.889	2336.	0.009	0.007
1.800	0.000	0.62	83.	0.996	0.992	0.986	2337.	0.010	0.008
1.900	0.000	0.71	91.	1.102	1.098	1.090	2339.	0.012	0.009
2.000	0.001	0.80	101.	1.216	1.212	1.204	2341.	0.013	0.010
2.100	0.001	0.91	111.	1.341	1.336	1.327	2343.	0.014	0.011
2.200	0.001	1.02	122.	1.475	1.470	1.460	2345.	0.016	0.013
2.300	0.001	1.15	134.	1.620	1.615	1.604	2347.	0.018	0.014
2.400	0.001	1.29	147.	1.777	1.771	1.759	2349.	0.019	0.016
2.500	0.001	1.44	161.	1.945	1.938	1.925	2351.	0.021	0.018
2.600	0.001	1.60	176.	2.126	2.118	2.104	2354.	0.023	0.019
2.700	0.001	1.78	192.	2.319	2.312	2.296	2356.	0.026	0.021
2.800	0.002	1.98	209.	2.527	2.519	2.502	2358.	0.028	0.024
2.900	0.002	2.19	227.	2.750	2.740	2.722	2361.	0.030	0.026
3.000	0.002	2.42	246.	2.987	2.977	2.957	2363.	0.033	0.028
3.100	0.002	2.68	267.	3.241	3.230	3.208	2365.	0.036	0.031
3.200	0.003	2.95	289.	3.511	3.499	3.475	2368.	0.039	0.034
3.300	0.003	3.24	313.	3.798	3.785	3.760	2370.	0.042	0.037
3.400	0.003	3.56	338.	4.104	4.090	4.062	2373.	0.046	0.041
3.500	0.004	3.91	364.	4.428	4.413	4.383	2375.	0.050	0.044
3.600	0.004	4.28	392.	4.771	4.755	4.723	2378.	0.054	0.048
3.700	0.004	4.67	422.	5.134	5.117	5.083	2380.	0.058	0.052
3.800	0.005	5.10	453.	5.518	5.500	5.463	2382.	0.062	0.056
3.900	0.005	5.56	486.	5.923	5.903	5.863	2385.	0.067	0.061
4.000	0.006	6.06	520.	6.349	6.328	6.286	2387.	0.072	0.066
4.100	0.007	6.58	557.	6.798	6.775	6.730	2390.	0.077	0.071
4.200	0.007	7.15	595.	7.269	7.245	7.196	2392.	0.082	0.076
4.300	0.008	7.75	635.	7.763	7.737	7.686	2394.	0.088	0.082
4.400	0.009	8.39	676.	8.280	8.253	8.198	2397.	0.094	0.088
4.500	0.010	9.08	720.	8.821	8.791	8.733	2399.	0.101	0.095
4.600	0.011	9.81	765.	9.384	9.353	9.291	2401.	0.107	0.102
4.700	0.012	10.58	813.	9.972	9.938	9.872	2403.	0.115	0.109
4.800	0.013	11.40	862.	10.582	10.547	10.477	2406.	0.122	0.116
4.900	0.014	12.27	912.	11.215	11.178	11.104	2408.	0.130	0.124
5.000	0.015	13.19	965.	11.871	11.832	11.753	2410.	0.138	0.132
5.100	0.017	14.16	1019.	12.549	12.507	12.424	2412.	0.147	0.141
5.200	0.018	15.19	1075.	13.248	13.204	13.116	2414.	0.156	0.150
5.300	0.020	16.27	1132.	13.967	13.921	13.829	2416.	0.165	0.159
5.400	0.021	17.41	1191.	14.706	14.658	14.560	2418.	0.175	0.169
5.500	0.023	18.61	1251.	15.463	15.412	15.310	2420.	0.185	0.179
5.600	0.025	19.87	1312.	16.237	16.183	16.076	2421.	0.195	0.190

5.700	0.027	21.18	1374.	17.025	16.969	16.857	2423.	0.206	0.201
5.800	0.029	22.56	1437.	17.828	17.769	17.652	2425.	0.218	0.212
5.900	0.032	24.00	1501.	18.641	18.580	18.458	2426.	0.230	0.224
6.000	0.034	25.50	1565.	19.465	19.401	19.273	2428.	0.242	0.235
6.100	0.037	27.07	1629.	20.295	20.228	20.096	2430.	0.255	0.248
6.200	0.040	28.70	1694.	21.130	21.061	20.923	2431.	0.268	0.260
6.300	0.043	30.39	1758.	21.967	21.895	21.752	2432.	0.281	0.273
6.400	0.046	32.15	1823.	22.804	22.729	22.581	2434.	0.295	0.286
6.500	0.049	33.97	1886.	23.637	23.560	23.407	2435.	0.310	0.300
6.600	0.052	35.85	1949.	24.465	24.385	24.226	2436.	0.324	0.314
6.700	0.056	37.79	2010.	25.283	25.201	25.037	2438.	0.339	0.328
6.800	0.060	39.79	2070.	26.090	26.005	25.837	2439.	0.355	0.342
6.900	0.064	41.85	2129.	26.881	26.795	26.621	2440.	0.371	0.356
7.000	0.068	43.96	2185.	27.655	27.566	27.388	2441.	0.387	0.371
7.100	0.073	46.13	2240.	28.408	28.317	28.135	2442.	0.404	0.385
7.200	0.078	48.36	2292.	29.138	29.045	28.858	2443.	0.421	0.400
7.300	0.083	50.63	2341.	29.841	29.746	29.555	2444.	0.438	0.415
7.400	0.088	52.95	2388.	30.516	30.419	30.224	2445.	0.455	0.430
7.500	0.093	55.31	2432.	31.159	31.060	30.862	2446.	0.473	0.445
7.600	0.099	57.72	2472.	31.769	31.668	31.466	2447.	0.491	0.460
7.700	0.105	60.16	2509.	32.342	32.240	32.036	2447.	0.509	0.475
7.800	0.111	62.64	2542.	32.879	32.775	32.568	2448.	0.527	0.490
7.900	0.117	65.14	2571.	33.376	33.271	33.061	2449.	0.545	0.505
8.000	0.124	67.68	2597.	33.832	33.726	33.514	2450.	0.564	0.519
8.100	0.131	70.23	2618.	34.246	34.139	33.926	2450.	0.582	0.534
8.200	0.138	72.81	2636.	34.617	34.510	34.295	2451.	0.601	0.548
8.300	0.145	75.40	2649.	34.945	34.837	34.621	2452.	0.619	0.563
8.400	0.153	78.01	2659.	35.228	35.120	34.903	2452.	0.637	0.577
8.500	0.161	80.62	2681.	35.468	35.359	35.140	2453.	0.655	0.591
8.600	0.169	83.26	2700.	35.664	35.554	35.334	2453.	0.673	0.604
8.700	0.178	85.92	2714.	35.814	35.704	35.483	2454.	0.691	0.618
8.800	0.186	88.59	2725.	35.921	35.810	35.588	2454.	0.708	0.631
8.900	0.195	91.26	2733.	35.984	35.873	35.650	2454.	0.726	0.643
8.997	0.204	93.86	2737.	36.004	35.892	35.669	2454.	0.742	0.656

LOCAL PRESSURE MAX DETECTED

9.000	0.205	93.94	2737.	36.004	35.892	35.669	2454.	0.743	0.656
9.100	0.214	96.63	2737.	35.982	35.870	35.647	2454.	0.759	0.668
9.200	0.224	99.31	2734.	35.919	35.807	35.584	2454.	0.775	0.680
9.300	0.234	101.99	2728.	35.815	35.704	35.482	2454.	0.791	0.692
9.400	0.244	104.66	2719.	35.674	35.563	35.342	2453.	0.806	0.703
9.500	0.255	107.32	2706.	35.496	35.385	35.165	2452.	0.821	0.714
9.600	0.266	109.97	2691.	35.282	35.172	34.953	2451.	0.836	0.725
9.700	0.277	112.60	2673.	35.034	34.925	34.708	2450.	0.849	0.735
9.800	0.288	115.21	2653.	34.755	34.647	34.431	2449.	0.863	0.745
9.900	0.300	117.80	2629.	34.446	34.339	34.125	2447.	0.875	0.755
10.000	0.312	120.37	2604.	34.109	34.003	33.791	2445.	0.887	0.764
10.055	0.319	121.78	2589.	33.911	33.806	33.594	2444.	0.894	0.769

LAYER TRANSITION 3 TO 4 ON LAT SURFACE OF PROPELLANT 1

10.100	0.324	122.91	2577.	33.745	33.640	33.430	2443.	0.899	0.773
10.200	0.336	125.42	2546.	33.348	33.244	33.037	2440.	0.910	0.782
10.300	0.349	127.90	2514.	32.921	32.818	32.613	2436.	0.920	0.790
10.400	0.362	130.35	2479.	32.467	32.366	32.164	2432.	0.929	0.798
10.500	0.375	132.76	2442.	31.991	31.892	31.693	2427.	0.938	0.806
10.600	0.389	135.14	2404.	31.496	31.398	31.202	2421.	0.946	0.814
10.700	0.402	137.48	2365.	30.986	30.889	30.697	2415.	0.953	0.821
10.800	0.416	139.77	2324.	30.463	30.368	30.178	2408.	0.960	0.828
10.900	0.430	142.03	2283.	29.930	29.837	29.651	2401.	0.966	0.834
11.000	0.444	144.25	2242.	29.390	29.299	29.116	2394.	0.972	0.840
11.100	0.459	146.43	2200.	28.845	28.756	28.576	2386.	0.977	0.847
11.200	0.474	148.57	2157.	28.298	28.210	28.034	2378.	0.982	0.852
11.300	0.489	150.66	2115.	27.750	27.664	27.492	2370.	0.987	0.858
11.400	0.504	152.71	2073.	27.203	27.119	26.950	2361.	0.991	0.863
11.500	0.519	154.73	2031.	26.659	26.576	26.410	2352.	0.994	0.868

11.600	0.535	156.70	1990.	26.118	26.037	25.875	2343.	0.998	0.873
11.677	0.547	158.19	1958.	25.704	25.624	25.465	2336.	1.000	0.877
PROPELLANT 1 BURNED OUT									
11.700	0.551	158.63	1947.	25.564	25.484	25.326	2333.	1.000	0.878
11.800	0.566	160.52	1901.	24.961	24.883	24.728	2322.	1.000	0.882
11.900	0.583	162.36	1856.	24.375	24.300	24.148	2310.	1.000	0.887
12.000	0.599	164.16	1812.	23.807	23.733	23.585	2299.	1.000	0.891
12.100	0.615	165.91	1770.	23.255	23.183	23.038	2287.	1.000	0.895
12.200	0.632	167.63	1729.	22.719	22.649	22.508	2276.	1.000	0.898
12.300	0.649	169.31	1690.	22.199	22.131	21.993	2265.	1.000	0.902
12.400	0.666	170.94	1652.	21.695	21.628	21.493	2254.	1.000	0.905
12.500	0.683	172.55	1615.	21.206	21.140	21.008	2243.	1.000	0.908
12.600	0.701	174.11	1580.	20.731	20.666	20.537	2232.	1.000	0.912
12.700	0.718	175.65	1546.	20.270	20.207	20.081	2221.	1.000	0.915
12.800	0.736	177.15	1513.	19.823	19.761	19.638	2211.	1.000	0.917
12.900	0.753	178.61	1481.	19.389	19.328	19.207	2200.	1.000	0.920
13.000	0.771	180.05	1450.	18.967	18.908	18.790	2190.	1.000	0.923
13.100	0.789	181.46	1420.	18.559	18.501	18.385	2179.	1.000	0.925
13.200	0.808	182.84	1392.	18.162	18.105	17.992	2169.	1.000	0.928
13.300	0.826	184.19	1364.	17.777	17.721	17.610	2159.	1.000	0.930
13.400	0.844	185.51	1337.	17.403	17.349	17.240	2149.	1.000	0.932
13.500	0.863	186.81	1312.	17.040	16.987	16.880	2139.	1.000	0.934
13.600	0.882	188.08	1287.	16.688	16.635	16.531	2129.	1.000	0.936
13.700	0.901	189.33	1263.	16.346	16.294	16.191	2120.	1.000	0.938
13.800	0.920	190.56	1240.	16.013	15.963	15.862	2110.	1.000	0.940
13.900	0.939	191.77	1218.	15.690	15.641	15.541	2101.	1.000	0.942
14.000	0.958	192.95	1196.	15.377	15.328	15.230	2091.	1.000	0.944
14.100	0.977	194.11	1176.	15.072	15.024	14.928	2082.	1.000	0.946
14.200	0.997	195.26	1156.	14.776	14.728	14.634	2073.	1.000	0.947
14.300	1.016	196.38	1136.	14.488	14.441	14.349	2064.	1.000	0.949
14.400	1.036	197.49	1118.	14.208	14.162	14.071	2055.	1.000	0.950
14.500	1.056	198.57	1100.	13.935	13.890	13.801	2046.	1.000	0.952
14.600	1.076	199.64	1083.	13.671	13.626	13.538	2037.	1.000	0.953
14.700	1.096	200.70	1066.	13.413	13.369	13.283	2028.	1.000	0.954
14.800	1.116	201.74	1051.	13.162	13.120	13.034	2019.	1.000	0.956
14.900	1.136	202.76	1035.	12.919	12.876	12.792	2011.	1.000	0.957
15.000	1.157	203.77	1021.	12.681	12.640	12.556	2002.	1.000	0.958
15.100	1.177	204.76	1004.	12.450	12.409	12.327	1994.	1.000	0.959
15.120	1.181	204.96	1000.	12.404	12.364	12.282	1992.	1.000	0.960
PROJECTILE EXIT									

MORTAR W/ MAIN CHG IBHVG2.506d.HILO DATE: TIME:

CONDITIONS AT:	METRIC PMAX	METRIC MUZZLE	ENGLISH PMAX	ENGLISH MUZZLE
TIME (MS):	8.997	15.120		
TRAVEL (M):	0.2042	1.1811		
VELOCITY (M/S)	93.86	204.96		672.
ACCELERATION (G):	2737.	1000.		
BREECH PRESS (MPA):	36.0039	12.4045	5222.	
MEAN PRESS (MPA):	35.8924	12.3637		
BASE PRESS (MPA):	35.6693	12.2822		
MEAN TEMP (K):	2454.	1992.		
Z CHARGE 1 (-):	0.742	1.000		
Z CHARGE 2 (-):	0.656	0.960		

ENERGY BALANCE SUMMARY	JOULE	%
TOTAL CHEMICAL:	1258021.	100.00
(1) INTERNAL GAS:	876714.	69.69
(2) WORK AND LOSSES:	381307.	30.31
(A) PROJECTILE KINETIC:	295340.	23.48
(B) GAS KINETIC:	2037.	0.16
(C) PROJECTILE ROTATIONAL:	1.	0.00
(D) FRICTIONAL WORK TO TUBE:	0.	0.00
(E) OTHER FRICTIONAL WORK:	25599.	2.03
(F) WORK DONE AGAINST AIR:	1098.	0.09
(G) HEAT CONVECTED TO BORE:	57231.	4.55
(H) RECOIL ENERGY:	0.	0.00

LOADING DENSITY (KG/M3):	90.144
CHARGE WT/PROJECTILE WT:	0.021
PIEZOMETRIC EFFICIENCY:	0.595
EXPANSION RATIO:	5.270

INTENTIONALLY LEFT BLANK

Appendix H. Permeable Canister with Added Main Charge (solid discharge coefficient of 0.06)

```
 ERRTOL =    0.119209E-06
                                         IBHVG2.506d.HILO  DATE:              TIME:

  CARD   1 --> $GUN
  CARD   2 -->     NAME     = 'MORTAR'                   CHAM     = 0.0032283
  CARD   3 -->     GRVE     =    0.1219                  LAND     =    0.1219
  CARD   4 -->     TRAV     =    1.1811                  G/L      =    1.0000
  CARD   5 -->     TWST     =     999.0
  CARD   6 --> $INFO
  CARD   7 -->     DELT     =  0.12500E-04               DELP     =  0.10000E-03
  CARD   8 -->     INP      =  0                         OUT      =  0
  CARD   9 -->     POPT     =  1, 1, 1, 0, 0, 1
  CARD  10 -->     RUN      = 'MORTAR W/ MAIN CHG'
  CARD  11 --> $RESI
  CARD  12 -->     NPTS     =  3                         TRAV     = 0.0,   0.1524,   1.1684
  CARD  13 -->     PRES     = 0.0,   3.4474,   0.3447
  CARD  14 --> $PROJ
  CARD  15 -->     PRWT     =   14.0614
  CARD  16 --> $PRIM
  CARD  17 -->     NAME     = 'BPPELLETS'                GAMA     =    1.2500
  CARD  18 -->     FORC     =  313852.0                  COV      =  0.87789E-03
  CARD  19 -->     TEMP     =    2380.0                  CHWT     =  0.10115E-03
  CARD  20 --> $PROP
  CARD  21 -->     NAME     = 'MAIN CHG'                 NTBL     = -1
  CARD  22 -->     DEPL     = 0.0,0.0, 0.17424E-03       EX1L     =    0.7900
  CARD  23 -->     EX2L     =    0.7900                  EX3L     =    0.7900
  CARD  24 -->     EX4L     =    0.8900                  CF1L     = 0.0013602
  CARD  25 -->     CF2L     = 0.0013602                  CF3L     = 0.0013602
  CARD  26 -->     CF4L     = 0.0022374               RHOL  =  1550.1, 1550.1, 1550.1, 1550.1
  CARD  27 -->     GAML     =    1.2600,   1.2600,   1.2600,   1.2200
  CARD  28 -->     FRCL     =  866829.4, 866829.4, 866829.4,1105954.9
  CARD  29 -->     COVL     = 0.0011199,0.0011199,0.0011199, 0.99350E-03
  CARD  30 -->     TMPL     =    2070.0,   2070.0,   2070.0,   3350.0
  CARD  31 -->     GRAN     = 'CAKE'                     WRED     =    0.3000
  CARD  32 -->     ORGD     =  0.71120E-03               CHWT     =    0.2300
  CARD  33 --> $HILO
  CARD  34 -->     IBV      =  1                         NHOL     = 28
  CARD  35 -->     SHOL     = 0.0053010                  NPRP     =  1
  CARD  36 -->     VOLI     =  0.97929E-04               DCOF     =    0.8400
  CARD  37 -->     BURP     =    3.4474                  SDCF     =    0.0600
  CARD  38 --> $PROP
  CARD  39 -->     NAME     = 'CAN PROP'                 RHO      =    1550.1
  CARD  40 -->     GAMA     =    1.2100                  FORC     = 1169024.1
  CARD  41 -->     COV      =  0.96532E-03               TEMP     =    3720.0
  CARD  42 -->     CHWT     =    0.0600                  ALPH     =    0.9035
  CARD  43 -->     BETA     = 0.0020624                  GRAN     = 'BALL'
  CARD  44 -->     DIAM     = 0.0012446                  NTBL     =  0
  CARD  45 --> $END
```

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------------
- GUN TUBE -
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TYPE: MORTAR                  CHAMBER VOLUME (M3):  0.00323  TRAVEL (M):            1.18110
GROOVE DIAMETER (M): 0.12190  LAND DIAMETER (M):    0.12190  GROOVE/LAND RATIO (-):  1.000
TWIST (CALS/TURN):     999.0  BORE AREA (M2):       0.01167  HEAT-LOSS OPTION:           1
SHELL THICKNESS (M): 0.000102  SHELL CP (J/KG-K):   460.3161  SHELL DENSITY (KG/M3): 7861.0913
INITIAL SHELL TEMP (K): 293.  AIR H0 (W/M**2-K):    11.3482

--------------
- PROJECTILE -
--------------

TYPE:                              TOTAL WEIGHT (KG):       14.061    WEIGHT PREDICTOR
OPTION:      0

--------------
- RESISTANCE -
--------------

AIR RESISTANCE OPTION:       1  TUBE GAS INITIAL PRES (MPA) 0.000  WALL HEATING FRACTION: 0.000
RESISTIVE PRESSURE MULT INDEX: 3  RESISTIVE FACTO            1.000  FRICTION TABLE LENGTH: 3

I  TRAVEL (M)   PRESSURE (MPA)   I  TRAVEL (M)  PRESSURE (MPA)  I  TRAVEL (M)  PRESSURE (MPA)

1   0.000          0.000         2   0.152          3.447       3   1.168         0.345

-----------
- GENERAL -
-----------

MAX TIME STEP (S):      0.000012  PRINT STEP (S):      0.000100  MAX RELATIVE ERROR (-): 0.00200
PRINT OPTIONS:       1 1 1 0 0 1  STORE OPTION:              0  CONSTANT-PRESSURE OPTION:     0
GRADIENT MODEL: LAGRANGIAN        INPUT UNITS:   METRIC         OUTPUT UNITS:   METRIC

----------
- RECOIL -
----------

RECOIL OPTION:             0    TYPE:                  RECOILING WEIGHT (KG):       0.

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- HILO/PRIMER IGNITER -
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  IGNITER HAS  28 HOLES OF    0.0053010 M DIAMETER
  LAST PROPELLANT BURNS IN THE IGNITER
  IGNITER VOLUME IS   0.00009793 M3
  GAS DISCHARGE COEFFICIENT IS  0.8400
  SOLID DISCHARGE COEFFICIENT IS  0.0600
  BURST PRESSURE TO START VENTING OR BURST IS        3.447 MPA
  VENT/BURST SWITCH (1=VENT, 2=BURST) IS 1
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- PRIMER -
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TYPE: BPPELLETS                GAMMA (-):       1.2500    FORCE (J/KG):    313852.
COVOLUME (M3/KG):  8.7789E-04  FLAME TEMP (K):  2380.0    WEIGHT (KG):     0.000101

-------------
- CHARGE  1 -
-------------

TYPE: MAIN CHG               GRAINS:        0.78776E+06 CAKE  WEIGHT (KG):         0.2300
EROSIVE COEFF (-): 0.000000  CHARGE IGN CODE:            1    CHARGE IGN AT (S):  0.10000E+02
ORIG DIA (M): 0.7112E-03 %WEB REDUCT. : 0.30 THICKNESS (M): 0.4978E-03 DIAMETER (M): 0.7919E-03

                        PROPERTIES AT LAYER BOUNDARIES OF  LAT SURFACES
                              1ST         2ND         3RD         4TH

  AT DEPTH (M):              ------      ------  0.0000E+00  1.7424E-04
  ADJACENT LAYER WT %:       ------      ------      89.389      10.611
  DENSITY (KG/M3):           ------      ------    1550.100    1550.100
  GAMMA (-):                 ------      ------      1.2600      1.2200
  FORCE (J/KG):              ------      ------     866829.    1105955.
  COVOLUME (M3/KG):          ------      ------  1.1199E-03  9.9350E-04
  FLAME TEMP (K):            ------      ------      2070.0      3350.0
  MEAN PRESSURES (MPA):      ------      ------       0.000       0.000
  BURNING RATE EXPS:         ------      ------      0.7900      0.8900
  BURNING RATE COEFFS:       ------      ------  1.3602E-03  2.2374E-03

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- CHARGE  2 -
-------------

TYPE: CAN PROP                 GRAINS:        0.00000E+00 BALL  WEIGHT (KG):            0.0000
EROSIVE COEFF (-):   0.000000  CHARGE IGN CODE:              1  CHARGE IGN AT (S): 0.10000E+02
GRAIN DIAMETER (M):  0.000100

                        PROPERTIES AT LAYER BOUNDARIES OF  LAT SURFACES
                              1ST         2ND         3RD         4TH

  AT DEPTH (M):              ------      ------      ------  0.0000E+00
  ADJACENT LAYER WT %:       ------      ------      ------     100.000
  DENSITY (KG/M3):           ------      ------      ------    1550.100
  GAMMA (-):                 ------      ------      ------      1.2100
  FORCE (J/KG):              ------      ------      ------    1169024.
  COVOLUME (M3/KG):          ------      ------      ------  9.6532E-04
  FLAME TEMP (K):            ------      ------      ------      3720.0
  BURNING RATE EXPS:         ------      ------      ------      0.9035
  BURNING RATE COEFFS:       ------      ------      ------  2.0624E-03

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- CHARGE  3 -
-------------

TYPE: CAN PROP                GRAINS:         38345.   BALL  WEIGHT (KG):           0.0600
EROSIVE COEFF (-):  0.000000  CHARGE IGN CODE:         0    CHARGE IGN AT (S): 0.00000E+00
GRAIN DIAMETER (M): 0.001245
```

PROPERTIES AT LAYER BOUNDARIES OF LAT SURFACES

	1ST	2ND	3RD	4TH
AT DEPTH (M):	------	------	------	0.0000E+00
ADJACENT LAYER WT %:	------	------	------	100.000
DENSITY (KG/M3):	------	------	------	1550.100
GAMMA (-):	------	------	------	1.2100
FORCE (J/KG):	------	------	------	1169024.
COVOLUME (M3/KG):	------	------	------	9.6532E-04
FLAME TEMP (K):	------	------	------	3720.0
BURNING RATE EXPS:	------	------	------	0.9035
BURNING RATE COEFFS:	------	------	------	2.0624E-03

MORTAR W/ MAIN CHG IBHVG2.506d.HILO DATE: TIME:

TIME (MS)	TRAV (M)	VEL (M/S)	ACC (G)	BREECH PRESS (MPA)	MEAN PRESS (MPA)	BASE PRESS (MPA)	MEAN TEMP (K)	FRAC BURN 1	FRAC BURN 2	FRAC BURN 3
0.000	0.000	0.00	9.	0.103	0.102	0.102	293.	0.000	0.000	0.000
0.002	0.000	0.00	9.	0.103	0.102	0.102	293.	0.000	0.000	0.000
LOCAL PRESSURE MAX DETECTED										
BARREL RESISTANCE OVERCOME - PROJECTILE MOVING										
0.100	0.000	0.01	9.	0.103	0.102	0.102	293.	0.000	0.000	0.001
0.123	0.000	0.01	9.	0.103	0.102	0.102	293.	0.000	0.000	0.002
LOCAL PRESSURE MIN DETECTED										
IGNITER IS STARTING TO VENT										
0.200	0.000	0.02	13.	0.159	0.159	0.158	434.	0.000	0.000	0.026
PROPELLANT 2 IGNITED										
0.300	0.000	0.04	23.	0.277	0.276	0.275	698.	0.001	0.000	0.061
0.400	0.000	0.07	37.	0.445	0.444	0.441	1010.	0.001	0.000	0.098
0.500	0.000	0.11	55.	0.659	0.657	0.654	1322.	0.002	0.001	0.134
0.600	0.000	0.18	77.	0.916	0.913	0.908	1602.	0.003	0.001	0.171
0.700	0.000	0.26	102.	1.212	1.209	1.202	1836.	0.004	0.002	0.206
0.800	0.000	0.38	130.	1.546	1.542	1.533	2024.	0.006	0.003	0.241
0.900	0.000	0.52	160.	1.913	1.908	1.898	2172.	0.007	0.004	0.274
1.000	0.000	0.69	194.	2.311	2.305	2.292	2285.	0.009	0.006	0.306
1.100	0.000	0.90	229.	2.736	2.729	2.713	2370.	0.012	0.008	0.337
1.200	0.000	1.14	267.	3.184	3.175	3.158	2433.	0.015	0.010	0.366
1.300	0.000	1.42	306.	3.652	3.642	3.622	2480.	0.018	0.012	0.393
1.400	0.001	1.74	346.	4.137	4.126	4.103	2513.	0.021	0.015	0.419
1.500	0.001	2.10	387.	4.637	4.624	4.598	2536.	0.025	0.018	0.443
1.600	0.001	2.50	430.	5.150	5.135	5.107	2551.	0.029	0.021	0.466
1.700	0.001	2.94	474.	5.674	5.658	5.627	2560.	0.034	0.025	0.487
1.800	0.002	3.43	518.	6.209	6.191	6.157	2564.	0.038	0.029	0.507
1.900	0.002	3.96	563.	6.754	6.735	6.698	2564.	0.044	0.033	0.525
2.000	0.002	4.53	609.	7.310	7.290	7.249	2561.	0.049	0.038	0.542
2.100	0.003	5.15	655.	7.874	7.852	7.808	2557.	0.055	0.043	0.558
2.200	0.003	5.82	701.	8.439	8.416	8.369	2549.	0.061	0.048	0.572
2.300	0.004	6.53	748.	9.007	8.982	8.932	2540.	0.068	0.054	0.584
2.400	0.005	7.29	795.	9.584	9.558	9.504	2531.	0.075	0.061	0.594
2.500	0.006	8.09	843.	10.180	10.152	10.095	2522.	0.082	0.067	0.604
2.600	0.006	8.94	894.	10.797	10.767	10.707	2513.	0.089	0.075	0.613
2.700	0.007	9.84	945.	11.437	11.405	11.342	2506.	0.097	0.082	0.622
2.800	0.008	10.80	999.	12.099	12.066	11.999	2499.	0.106	0.090	0.631
2.900	0.010	11.80	1054.	12.784	12.748	12.677	2492.	0.114	0.099	0.640
3.000	0.011	12.86	1111.	13.489	13.452	13.377	2487.	0.123	0.108	0.648
3.100	0.012	13.98	1169.	14.215	14.176	14.097	2481.	0.133	0.117	0.657
3.200	0.014	15.16	1229.	14.960	14.919	14.836	2476.	0.143	0.127	0.665
3.300	0.015	16.39	1290.	15.724	15.680	15.593	2472.	0.153	0.137	0.673
3.400	0.017	17.69	1352.	16.504	16.458	16.366	2468.	0.164	0.147	0.681
3.500	0.019	19.05	1415.	17.299	17.251	17.155	2464.	0.175	0.158	0.689
3.600	0.021	20.47	1480.	18.108	18.057	17.957	2461.	0.186	0.169	0.697
3.700	0.023	21.95	1544.	18.928	18.875	18.771	2458.	0.198	0.181	0.705
3.800	0.025	23.49	1610.	19.757	19.703	19.593	2455.	0.211	0.193	0.713
3.900	0.027	25.10	1675.	20.594	20.537	20.423	2452.	0.224	0.205	0.721
4.000	0.030	26.78	1741.	21.436	21.376	21.258	2450.	0.237	0.218	0.729
4.100	0.033	28.52	1806.	22.279	22.217	22.094	2448.	0.251	0.231	0.736
4.200	0.036	30.32	1871.	23.122	23.058	22.930	2446.	0.265	0.245	0.744
4.300	0.039	32.19	1936.	23.961	23.895	23.763	2444.	0.280	0.258	0.751
4.400	0.042	34.12	1999.	24.795	24.726	24.590	2442.	0.295	0.272	0.759
4.500	0.046	36.11	2061.	25.619	25.548	25.407	2441.	0.310	0.287	0.766
4.600	0.049	38.16	2122.	26.431	26.358	26.213	2440.	0.326	0.301	0.773
4.700	0.053	40.27	2182.	27.228	27.153	27.003	2438.	0.342	0.316	0.780
4.800	0.057	42.44	2239.	28.006	27.930	27.776	2437.	0.358	0.331	0.787
4.900	0.062	44.66	2294.	28.764	28.685	28.528	2436.	0.375	0.347	0.794
5.000	0.066	46.94	2347.	29.498	29.417	29.256	2435.	0.392	0.362	0.801

5.100	0.071	49.26	2397.	30.205	30.122	29.957	2434.	0.410	0.378	0.808
5.200	0.076	51.64	2444.	30.883	30.798	30.630	2434.	0.428	0.393	0.815
5.300	0.082	54.06	2488.	31.529	31.443	31.271	2433.	0.446	0.409	0.821
5.400	0.087	56.52	2529.	32.141	32.053	31.879	2433.	0.464	0.425	0.828
5.500	0.093	59.01	2566.	32.717	32.628	32.450	2432.	0.482	0.440	0.834
5.600	0.099	61.55	2600.	33.255	33.164	32.984	2432.	0.501	0.456	0.840
5.700	0.105	64.11	2630.	33.753	33.661	33.479	2431.	0.519	0.472	0.846
5.800	0.112	66.70	2655.	34.209	34.117	33.933	2431.	0.538	0.487	0.852
5.900	0.119	69.32	2677.	34.624	34.531	34.345	2431.	0.557	0.503	0.858
6.000	0.126	71.95	2695.	34.995	34.901	34.714	2430.	0.576	0.518	0.863
6.100	0.133	74.60	2708.	35.322	35.228	35.039	2430.	0.595	0.534	0.869
6.200	0.140	77.26	2717.	35.605	35.510	35.321	2430.	0.613	0.549	0.874
6.300	0.148	79.93	2722.	35.843	35.748	35.558	2430.	0.632	0.563	0.879
6.400	0.156	82.60	2732.	36.036	35.941	35.750	2430.	0.650	0.578	0.884
6.500	0.165	85.29	2746.	36.186	36.090	35.898	2430.	0.669	0.592	0.889
6.600	0.174	87.99	2757.	36.291	36.195	36.002	2429.	0.687	0.606	0.894
6.700	0.182	90.69	2764.	36.353	36.256	36.062	2429.	0.705	0.620	0.899
6.795	0.191	93.27	2768.	36.372	36.275	36.081	2429.	0.721	0.633	0.903

LOCAL PRESSURE MAX DETECTED

6.800	0.192	93.41	2768.	36.371	36.274	36.080	2429.	0.722	0.634	0.903
6.900	0.201	96.12	2769.	36.348	36.251	36.057	2428.	0.739	0.647	0.907
7.000	0.211	98.84	2766.	36.284	36.187	35.993	2428.	0.756	0.660	0.911
7.100	0.221	101.55	2759.	36.180	36.083	35.889	2427.	0.772	0.672	0.915
7.200	0.231	104.25	2750.	36.038	35.941	35.747	2427.	0.788	0.685	0.919
7.300	0.242	106.94	2737.	35.858	35.762	35.569	2426.	0.804	0.697	0.923
7.400	0.253	109.61	2722.	35.644	35.548	35.356	2425.	0.819	0.708	0.926
7.500	0.264	112.27	2704.	35.396	35.300	35.110	2424.	0.833	0.719	0.930
7.600	0.275	114.92	2683.	35.116	35.021	34.832	2422.	0.847	0.730	0.933
7.700	0.287	117.54	2660.	34.806	34.712	34.525	2421.	0.860	0.741	0.936
7.800	0.299	120.13	2635.	34.469	34.376	34.189	2419.	0.873	0.751	0.939
7.900	0.311	122.70	2607.	34.105	34.013	33.828	2417.	0.885	0.761	0.942
7.972	0.320	124.55	2586.	33.826	33.735	33.552	2415.	0.894	0.767	0.944

LAYER TRANSITION 3 TO 4 ON LAT SURFACE OF PROPELLANT 1

8.000	0.323	125.24	2577.	33.717	33.626	33.443	2414.	0.897	0.770	0.945
8.100	0.336	127.76	2545.	33.299	33.209	33.028	2411.	0.908	0.779	0.947
8.200	0.349	130.23	2511.	32.852	32.763	32.585	2407.	0.918	0.788	0.950
8.300	0.362	132.68	2475.	32.381	32.293	32.118	2403.	0.928	0.796	0.952
8.400	0.375	135.09	2437.	31.889	31.803	31.630	2398.	0.936	0.805	0.954
8.500	0.389	137.46	2398.	31.380	31.295	31.124	2392.	0.944	0.812	0.957
8.600	0.403	139.79	2357.	30.856	30.772	30.605	2386.	0.952	0.820	0.959
8.700	0.417	142.08	2316.	30.322	30.239	30.075	2379.	0.959	0.827	0.961
8.800	0.431	144.33	2274.	29.779	29.698	29.536	2372.	0.965	0.834	0.962
8.900	0.446	146.54	2231.	29.230	29.150	28.992	2365.	0.971	0.840	0.964
9.000	0.460	148.71	2189.	28.677	28.600	28.444	2357.	0.976	0.847	0.966
9.100	0.475	150.83	2146.	28.124	28.047	27.894	2349.	0.981	0.853	0.967
9.200	0.491	152.91	2103.	27.570	27.495	27.345	2341.	0.986	0.859	0.969
9.300	0.506	154.96	2061.	27.018	26.945	26.798	2332.	0.990	0.864	0.970
9.400	0.522	156.96	2019.	26.470	26.398	26.254	2323.	0.993	0.869	0.972
9.500	0.537	158.91	1977.	25.926	25.856	25.714	2314.	0.997	0.874	0.973
9.600	0.553	160.83	1936.	25.388	25.319	25.181	2305.	1.000	0.879	0.974
9.606	0.554	160.95	1933.	25.355	25.286	25.148	2304.	1.000	0.880	0.974

PROPELLANT 1 BURNED OUT

9.700	0.569	162.71	1889.	24.787	24.719	24.584	2293.	1.000	0.884	0.975
9.800	0.586	164.54	1844.	24.199	24.133	24.001	2282.	1.000	0.888	0.977
9.900	0.602	166.33	1800.	23.629	23.564	23.436	2270.	1.000	0.893	0.978
10.000	0.619	168.07	1758.	23.075	23.013	22.887	2259.	1.000	0.897	0.979
10.100	0.636	169.77	1717.	22.539	22.477	22.355	2248.	1.000	0.900	0.980
10.200	0.653	171.44	1678.	22.019	21.959	21.838	2237.	1.000	0.904	0.980
10.300	0.670	173.07	1640.	21.514	21.455	21.338	2226.	1.000	0.908	0.981
10.400	0.688	174.66	1603.	21.024	20.967	20.852	2215.	1.000	0.911	0.982
10.500	0.705	176.21	1568.	20.550	20.494	20.381	2204.	1.000	0.914	0.983
10.600	0.723	177.73	1534.	20.089	20.035	19.925	2193.	1.000	0.917	0.984
10.700	0.741	179.22	1501.	19.643	19.589	19.482	2183.	1.000	0.920	0.984

10.800	0.759	180.67	1469.	19.210	19.157	19.052	2172.	1.000	0.923	0.985
10.900	0.777	182.10	1438.	18.790	18.738	18.635	2162.	1.000	0.926	0.986
11.000	0.795	183.49	1409.	18.382	18.332	18.231	2152.	1.000	0.928	0.986
11.100	0.814	184.86	1380.	17.987	17.938	17.839	2142.	1.000	0.931	0.987
11.200	0.832	186.20	1353.	17.604	17.555	17.458	2132.	1.000	0.933	0.987
11.300	0.851	187.52	1326.	17.231	17.184	17.088	2122.	1.000	0.935	0.988
11.400	0.870	188.80	1301.	16.870	16.823	16.730	2112.	1.000	0.938	0.988
11.500	0.889	190.07	1276.	16.519	16.474	16.382	2102.	1.000	0.940	0.989
11.600	0.908	191.31	1252.	16.179	16.134	16.044	2092.	1.000	0.942	0.989
11.700	0.927	192.52	1229.	15.848	15.804	15.716	2083.	1.000	0.944	0.990
11.800	0.946	193.72	1207.	15.527	15.484	15.397	2073.	1.000	0.945	0.990
11.900	0.966	194.89	1186.	15.215	15.173	15.088	2064.	1.000	0.947	0.990
12.000	0.985	196.04	1165.	14.912	14.871	14.787	2055.	1.000	0.949	0.991
12.100	1.005	197.18	1146.	14.618	14.577	14.495	2046.	1.000	0.951	0.991
12.200	1.025	198.29	1127.	14.332	14.292	14.211	2037.	1.000	0.952	0.991
12.300	1.044	199.39	1108.	14.054	14.014	13.934	2028.	1.000	0.954	0.992
12.400	1.064	200.46	1091.	13.784	13.745	13.666	2019.	1.000	0.955	0.992
12.500	1.084	201.53	1074.	13.521	13.482	13.405	2010.	1.000	0.957	0.992
12.600	1.105	202.57	1058.	13.265	13.227	13.151	2001.	1.000	0.958	0.993
12.700	1.125	203.60	1042.	13.017	12.979	12.904	1993.	1.000	0.959	0.993
12.800	1.145	204.61	1027.	12.775	12.738	12.664	1984.	1.000	0.961	0.993
12.900	1.166	205.61	1012.	12.540	12.503	12.430	1976.	1.000	0.962	0.993
12.974	1.181	206.34	999.	12.370	12.334	12.262	1970.	1.000	0.963	0.994

IN THE IGNITER

TIME (MS)	MEAN PRESS MPA	MEAM TEMP K	MDOT IGNI KG/S	G MASS OUT KG	FRAC BURN 1	SLD EXIT 1
0.000	0.7218	1252.8	0.000	0.0000	0.0000	0.0000
0.002	0.7409	1276.8	0.000	0.0000	0.0000	0.0000
0.100	2.6672	2560.2	0.000	0.0000	0.0015	0.0000
0.123	3.4479	2775.5	0.000	0.0000	0.0021	0.0000
IGNITER IS STARTING TO VENT						
0.200	5.1757	3251.7	1.761	0.0001	0.0264	0.0013
0.300	7.6036	3527.7	2.389	0.0003	0.0614	0.0031
0.400	10.1238	3636.4	3.079	0.0006	0.0978	0.0049
0.500	12.6002	3681.5	3.780	0.0009	0.1343	0.0066
0.600	14.8932	3701.2	4.441	0.0014	0.1705	0.0082
0.700	16.8794	3710.4	5.019	0.0018	0.2061	0.0097
0.800	18.4668	3714.9	5.483	0.0024	0.2407	0.0112
0.900	19.6026	3717.1	5.817	0.0029	0.2742	0.0126
1.000	20.2729	3718.3	6.013	0.0035	0.3063	0.0138
1.100	20.4971	3719.0	6.078	0.0041	0.3370	0.0150
1.200	20.3196	3719.4	6.025	0.0047	0.3661	0.0162
1.300	19.8004	3719.6	5.871	0.0053	0.3935	0.0172
1.400	19.0064	3719.8	5.635	0.0059	0.4193	0.0182
1.500	18.0054	3719.8	5.338	0.0064	0.4435	0.0192
1.600	16.8608	3719.9	4.999	0.0070	0.4661	0.0201
1.700	15.6287	3719.9	4.633	0.0074	0.4872	0.0209
1.800	14.3565	3720.0	4.256	0.0079	0.5068	0.0217
1.900	13.0830	3720.0	3.879	0.0083	0.5252	0.0225
2.000	11.8278	3720.0	3.517	0.0087	0.5424	0.0232
2.100	10.7151	3720.0	3.013	0.0090	0.5582	0.0239
2.200	10.0619	3720.0	2.434	0.0093	0.5721	0.0245
2.300	9.9952	3720.0	2.003	0.0095	0.5838	0.0250
2.400	10.3423	3720.0	1.829	0.0097	0.5941	0.0254
2.500	10.8707	3720.0	1.808	0.0099	0.6037	0.0258
2.600	11.4668	3720.0	1.839	0.0100	0.6129	0.0261
2.700	12.0965	3720.0	1.883	0.0102	0.6219	0.0264
2.800	12.7510	3720.0	1.930	0.0104	0.6308	0.0267
2.900	13.4281	3720.0	1.977	0.0106	0.6395	0.0270
3.000	14.1265	3720.0	2.025	0.0108	0.6481	0.0272

3.100	14.8453	3720.0	2.072	0.0110	0.6566	0.0275
3.200	15.5834	3720.0	2.119	0.0112	0.6649	0.0277
3.300	16.3395	3720.0	2.165	0.0114	0.6732	0.0279
3.400	17.1121	3720.0	2.210	0.0117	0.6813	0.0282
3.500	17.8997	3720.0	2.254	0.0119	0.6894	0.0284
3.600	18.7004	3720.0	2.297	0.0121	0.6974	0.0285
3.700	19.5123	3720.0	2.338	0.0123	0.7053	0.0287
3.800	20.3332	3720.0	2.377	0.0126	0.7131	0.0289
3.900	21.1610	3720.0	2.415	0.0128	0.7209	0.0291
4.000	21.9930	3720.0	2.451	0.0131	0.7285	0.0292
4.100	22.8267	3720.0	2.484	0.0133	0.7362	0.0294
4.200	23.6595	3720.0	2.515	0.0136	0.7437	0.0295
4.300	24.4887	3720.0	2.543	0.0138	0.7512	0.0296
4.400	25.3112	3720.0	2.569	0.0141	0.7586	0.0297
4.500	26.1242	3720.0	2.592	0.0143	0.7659	0.0299
4.600	26.9247	3720.0	2.612	0.0146	0.7731	0.0300
4.700	27.7098	3720.0	2.629	0.0148	0.7803	0.0301
4.800	28.4765	3720.0	2.643	0.0151	0.7873	0.0302
4.900	29.2218	3720.0	2.654	0.0154	0.7943	0.0303
5.000	29.9431	3720.0	2.661	0.0156	0.8012	0.0303
5.100	30.6375	3720.0	2.665	0.0159	0.8079	0.0304
5.200	31.3025	3720.0	2.666	0.0162	0.8146	0.0305
5.300	31.9356	3720.0	2.664	0.0164	0.8211	0.0306
5.400	32.5345	3720.0	2.658	0.0167	0.8276	0.0306
5.500	33.0972	3720.0	2.649	0.0170	0.8339	0.0307
5.600	33.6218	3720.0	2.637	0.0172	0.8401	0.0308
5.700	34.1067	3720.0	2.622	0.0175	0.8461	0.0308
5.800	34.5504	3720.0	2.603	0.0178	0.8520	0.0309
5.900	34.9518	3720.0	2.582	0.0180	0.8578	0.0309
6.000	35.3101	3720.0	2.558	0.0183	0.8634	0.0310
6.100	35.6244	3720.0	2.532	0.0185	0.8689	0.0310
6.200	35.8945	3720.0	2.503	0.0188	0.8743	0.0311
6.300	36.1200	3720.0	2.472	0.0190	0.8795	0.0311
6.400	36.3012	3720.0	2.438	0.0193	0.8845	0.0311
6.500	36.4382	3720.0	2.403	0.0195	0.8894	0.0312
6.600	36.5314	3720.0	2.366	0.0198	0.8941	0.0312
6.700	36.5813	3720.0	2.327	0.0200	0.8987	0.0312
6.795	36.5893	3720.0	2.290	0.0202	0.9029	0.0313
6.800	36.5885	3720.0	2.288	0.0202	0.9031	0.0313
6.900	36.5541	3720.0	2.246	0.0204	0.9074	0.0313
7.000	36.4790	3720.0	2.204	0.0207	0.9115	0.0313
7.100	36.3646	3720.0	2.161	0.0209	0.9155	0.0314
7.200	36.2121	3720.0	2.117	0.0211	0.9193	0.0314
7.300	36.0232	3720.0	2.072	0.0213	0.9229	0.0314
7.400	35.7994	3720.0	2.027	0.0215	0.9265	0.0314
7.500	35.5425	3720.0	1.982	0.0217	0.9298	0.0314
7.600	35.2541	3720.0	1.936	0.0219	0.9331	0.0314
7.700	34.9363	3720.0	1.890	0.0221	0.9362	0.0315
7.800	34.5908	3720.0	1.844	0.0223	0.9392	0.0315
7.900	34.2195	3720.0	1.798	0.0225	0.9420	0.0315
7.972	33.9354	3720.0	1.765	0.0226	0.9440	0.0315
8.000	33.8244	3720.0	1.753	0.0227	0.9447	0.0315
8.100	33.4013	3720.0	1.715	0.0228	0.9473	0.0315
8.200	32.9496	3720.0	1.675	0.0230	0.9498	0.0315
8.300	32.4731	3720.0	1.634	0.0232	0.9522	0.0315
8.400	31.9759	3720.0	1.592	0.0233	0.9544	0.0316
8.500	31.4612	3720.0	1.549	0.0235	0.9566	0.0316
8.600	30.9326	3720.0	1.506	0.0236	0.9586	0.0316
8.700	30.3929	3720.0	1.462	0.0238	0.9606	0.0316
8.800	29.8450	3720.0	1.418	0.0239	0.9624	0.0316
8.900	29.2914	3720.0	1.375	0.0241	0.9642	0.0316
9.000	28.7343	3720.0	1.332	0.0242	0.9659	0.0316
9.100	28.1759	3720.0	1.289	0.0243	0.9674	0.0316

9.200	27.6179	3720.0	1.247	0.0245	0.9690	0.0316
9.300	27.0620	3720.0	1.206	0.0246	0.9704	0.0316
9.400	26.5096	3720.0	1.165	0.0247	0.9717	0.0316
9.500	25.9620	3720.0	1.125	0.0248	0.9730	0.0316
9.600	25.4202	3720.0	1.087	0.0249	0.9743	0.0316
9.606	25.3872	3720.0	1.085	0.0249	0.9743	0.0316
9.700	24.8263	3720.0	1.103	0.0250	0.9754	0.0316
9.800	24.2337	3720.0	1.057	0.0251	0.9765	0.0317
9.900	23.6590	3720.0	1.013	0.0252	0.9776	0.0317
10.000	23.1017	3720.0	0.972	0.0253	0.9786	0.0317
10.100	22.5614	3720.0	0.932	0.0254	0.9795	0.0317
10.200	22.0376	3720.0	0.894	0.0255	0.9804	0.0317
10.300	21.5297	3720.0	0.858	0.0256	0.9813	0.0317
10.400	21.0373	3720.0	0.823	0.0257	0.9821	0.0317
10.500	20.5599	3720.0	0.791	0.0258	0.9828	0.0317
10.600	20.0971	3720.0	0.759	0.0259	0.9836	0.0317
10.700	19.6483	3720.0	0.730	0.0259	0.9842	0.0317
10.800	19.2131	3720.0	0.701	0.0260	0.9849	0.0317
10.900	18.7911	3720.0	0.674	0.0261	0.9855	0.0317
11.000	18.3818	3720.0	0.648	0.0261	0.9861	0.0317
11.100	17.9847	3720.0	0.624	0.0262	0.9867	0.0317
11.200	17.5996	3720.0	0.600	0.0263	0.9872	0.0317
11.300	17.2259	3720.0	0.578	0.0263	0.9877	0.0317
11.400	16.8633	3720.0	0.557	0.0264	0.9882	0.0317
11.500	16.5114	3720.0	0.536	0.0264	0.9887	0.0317
11.600	16.1698	3720.0	0.517	0.0265	0.9891	0.0317
11.700	15.8382	3720.0	0.498	0.0265	0.9896	0.0317
11.800	15.5162	3720.0	0.480	0.0266	0.9900	0.0317
11.900	15.2035	3720.0	0.463	0.0266	0.9903	0.0317
12.000	14.8997	3720.0	0.447	0.0267	0.9907	0.0317
12.100	14.6046	3720.0	0.431	0.0267	0.9911	0.0317
12.200	14.3179	3720.0	0.416	0.0268	0.9914	0.0317
12.300	14.0392	3720.0	0.402	0.0268	0.9917	0.0317
12.400	13.7684	3720.0	0.388	0.0268	0.9920	0.0317
12.500	13.5050	3720.0	0.375	0.0269	0.9923	0.0317
12.600	13.2489	3720.0	0.363	0.0269	0.9926	0.0317
12.700	12.9999	3720.0	0.351	0.0270	0.9929	0.0317
12.800	12.7575	3720.0	0.339	0.0270	0.9932	0.0317
12.900	12.5218	3720.0	0.328	0.0270	0.9934	0.0317
12.974	12.3522	3720.0	0.320	0.0271	0.9936	0.0317

PROJECTILE EXIT

MORTAR W/ MAIN CHG   IBHVG2.506d.HILO DATE: TIME:

CONDITIONS AT:	METRIC PMAX	METRIC MUZZLE	ENGLISH PMAX	ENGLISH MUZZLE
TIME (MS):	6.795	12.974		
TRAVEL (M):	0.1912	1.1811		
VELOCITY (M/S)	93.27	206.34		677.
ACCELERATION (G):	2768.	999.		
BREECH PRESS (MPA):	36.3716	12.3701	5275.	
MEAN PRESS (MPA):	36.2746	12.3341		
BASE PRESS (MPA):	36.0806	12.2622		
MEAN TEMP (K):	2429.	1970.		
Z CHARGE 1 (-):	0.721	1.000		
Z CHARGE 2 (-):	0.633	0.963		
Z CHARGE 3 (-):	0.903	0.994		

ENERGY BALANCE SUMMARY	JOULE	%
TOTAL CHEMICAL:	1256930.	100.00
(1) INTERNAL GAS:	871921.	69.37
(2) WORK AND LOSSES:	385009.	30.63
(A) PROJECTILE KINETIC:	299339.	23.82
(B) GAS KINETIC:	1824.	0.15
(C) PROJECTILE ROTATIONAL:	1.	0.00
(D) FRICTIONAL WORK TO TUBE:	0.	0.00
(E) OTHER FRICTIONAL WORK:	25599.	2.04
(F) WORK DONE AGAINST AIR:	1116.	0.09
(G) HEAT CONVECTED TO BORE:	57130.	4.55
(H) RECOIL ENERGY:	0.	0.00

LOADING DENSITY (KG/M3):	79.624
CHARGE WT/PROJECTILE WT:	0.018
PIEZOMETRIC EFFICIENCY:	0.597
EXPANSION RATIO:	5.270

Appendix I. Source Code for Subroutine VENTIG

```
      SUBROUTINE VENTIG(PIN,POUT,FIN,GIN,DISCF,DIAM,NHOLE,VTMDOT)
C
C                              ROBBINS, ANDERSON  DECEMBER 2005
C
C     FIND DM/DT FROM IGNITER TO CHAMBER
C
      COMMON /CONBLK/
     $ PI,PI2,PI3,PI4,RT3,GRAV,GCCF
C
C     ASSUMES PIN > POUT
C
      AREA=PI*(DIAM/2.0)**2
      COMPAR=POUT*((GIN+1.0)/2.0)**(GIN/(GIN-1.0))
C                JOHN, ISBN 0-205-08014-6, PP. 53-57
C
      PEXIT=POUT
      VMACH=1.0
      IF (PIN.GT.COMPAR) THEN
         PEXIT=PIN*(0.7719-0.174*GIN)
C                SHAPIRO, LCCCN 53-8869, P. 84
      ELSE
         VMACH=SQRT((2.0/(GIN-1.0))*((PIN/POUT)**((GIN-1.0)/GIN)-1.0))
C                JOHN, ISBN 0-205-08014-6, PP. 53-57
      ENDIF
C
      VTMDOT=DISCF*FLOAT(NHOLE)*AREA*PEXIT*VMACH*SQRT(GIN/FIN)
C                JOHN, ISBN 0-205-08014-6, PP. 53-57
C
      RETURN
      END
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Appendix J. Source Code for Subroutine VENTIS

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      SUBROUTINE VENTIS(DTMASS)
C
C       FIND SOLID MASS EJECTED FROM IGNITER TO CHAMBER
C                                R. ANDERSON  DECEMBER 2005
C
      IMPLICIT INTEGER (I-N)
      COMMON /CONBLK/
     $ PI,PI2,PI3,PI4,RT3,GRAV,GCCF
      COMMON /FRMBLK/
     $ NPERFS(40),INFLG,ICFLG(40),IBFLG(40),V0(40),DPTHB(3,40),NPABC,
     $ Z(40),IGRTYP(40),LYR(3,40),SURFP(40),SURFE(40),SURFL(40),
     $ SURFX(40),IFRG(40),LYRO(3,40),ICFLGO(40),IBFLGO(40),GRNWT(40),
     $ DTRANS(16,3,40),IFRGO(40),XLYRWT(15,40,3),VNOW(40),XZALL(40),
     $ XNUMGR(40),BNORM(40),EPSL,VP(40),ISFLG(3,40),ISFLGO(3,40),
     $ PFMDOT(40),PFETA(40),PFGAM(40),PFFRC(40)
      COMMON /PRPBLK/
     $ NPROP,GTYPE(40),NTAB(40),C(40),WO(40),WI(40),D(40),WM(40),
     $ PD(40),SW(40),GL(40),WD(40),TH(40),EL2D(40),EL2PD(40),WI2WO(40),
     $ RHOP(15,40),RHOE(15,40),RHOL(15,40),GAMMAP(15,40),GAMMAE(15,40),
     $ GAMMAL(15,40),FP(15,40),FE(15,40),FL(15,40),COVP(15,40),
     $ COVE(15,40),COVL(15,40),FLTMPP(15,40),FLTMPE(15,40),FLTMPL(15,40)
     $,DTRNSP(14,40),DTRNSE(14,40),DTRNSL(14,40),BRXL1(10,40),
     $ BRXL2(10,40),BRXL3(10,40),BRXL4(10,40),BRYL1(10,40),BRYL2(10,40),
     $ BRYL3(10,40),BRYL4(10,40),BRZL1(10,40),BRZL2(10,40),BRZL3(10,40),
     $ BRZL4(10,40),BRXE1(10,40),BRXE2(10,40),BRXE3(10,40),BRXE4(10,40),
     $ BRYE1(10,40),BRYE2(10,40),BRYE3(10,40),BRYE4(10,40),BRZE1(10,40)
      COMMON /PRPBLK/
     $ BRZE2(10,40),BRZE3(10,40),BRZE4(10,40),BRXP1(10,40),BRXP2(10,40),
     $ BRXP3(10,40),BRXP4(10,40),BRYP1(10,40),BRYP2(10,40),BRYP3(10,40),
     $ BRYP4(10,40),BRZP1(10,40),BRZP2(10,40),BRZP3(10,40),BRZP4(10,40),
     $ THRC(40),IGNC(40),CHID(7,40),RHOG(40),GAMMAG(40),FG(40),COVG(40),
     $ FLTMPG(40),ALPHAG(40),BETAG(40),EROS(40),FFDEP(20,40),
     $ FFSUR(20,40),NSURF(40),WEB(40),D2PD(40),FSP(14,40),FSE(14,40),
     $ FSL(14,40),FSR(14,40),EL2WD(40),WD2TH(40),NSLOTS(40),SW2D(40),
     $ THRS(3,40),IGNS(3,40),NRINGS(40),IPABC(40),DISCF(40),THRF(40),
     $ IPFRAC(40),ORGD(40),WRED(40),BRCOL(15,40),BREXL(15,40),NNLYR(40),
     $ DAFT(40),DFWD(40),SMLT(40)
      COMMON /DEQBLK/
     $ NDEQ,Y(300),YP(300),DT,DP,IDEQMP,IDEQG0,IDEQG1,IDEQG2,IDEQG3,
     $ IDEQBR,IDEQRW,IDEQMO,IDEQRX,IDEQRV,IDEQDR,IDEQP0,IDEQP1,IDEQP2,
     $ IDEQP3,IDEQMT,IDEQTI,IDEQPX,IDEQPV,IDEQRS,IDEQHL,IDEQMC
      COMMON /HLOBLK/
     $ NHOLE,SHOLE,NPRPI,VOLIGN,DCOEFI,BURSTP,SDCOEF,
     $ IBV,VFREEI,IGNCO(40),IPROP(2,40),
     $ THRCO(40),IGNSO(3,40),THRSO(3,40),NPRPIC,TOTCHI,TOTCCH,
     $ AIRMAS,PRMIGN,IDEQI0,IDEQI1,IDEQI2,IDEQI3,IDEQIM,IDEQID,
     $ IBVSWT,FRCIGN,GAMIGN,VDOTCI,TMIGN,KI,OLDVOL
C
      DATA DEPBK/0.0/
      SAVE DEPBK
C
      IF(IBV.NE.1.OR.YP(IDEQID).LE.0.0) RETURN
C
      I=NPROP-NPRPIC+1
      DO 10 J=I,NPROP
        IF(IBFLG(J).GT.0) GO TO 10
C
```

```
C          CHECK TO SEE THAT PARTICLES CAN GET THRU IGNITER HOLES
C
        PRAD=(3.0*VNOW(J)/(4.0*PI))**(1./3.)
        IF(2.*PRAD.GT.SHOLE) GO TO 10
C
C          CALCULATE FRACTION OF GAS LEAVING IGNITER CHAMBER
        PCT=DTMASS/Y(IDEQIM)
C          NUMBER OF IGNITER CHARGE GRAINS VENTED
        VNBRGR=PCT*XNUMGR(J)*SDCOEF
C          CALCULATE MASS OF VENTED SOLID
        VSOLID=VNBRGR*RHOL(4,J)*VNOW(J)
C          MASS LOST FROM IGNITER PROPELLANT
        Y(IDEQMC+J-1)=Y(IDEQMC+J-1)+VSOLID
C
        K=IPROP(1,J)
C
C          TOTAL MASS VENTED TO GHOST PROPELLANT
        C(K)=C(K)+VSOLID
C          CURRENT SOLID MASS OF GHOST PROPELLANT
        GSOLID=VNOW(K)*XNUMGR(K)*RHOL(4,K)+VSOLID
C          SET CURRENT NUMBER OF GRAINS IN IGNITER AND GHOST CHARGE
        XNUMGR(J)=XNUMGR(J)-VNBRGR
        XNUMGR(K)=XNUMGR(K)+VNBRGR
C          FIND AVERAGE VOLUME OF GRAINS IN GHOST CHARGE
        VNOW(K)=GSOLID/RHOL(4,K)/XNUMGR(K)
C          FIND SPHERE DIAMETER OF CURRENT GHOST GRAIN
        D(K)=2.*(3.0*VNOW(K)/(4.0*PI))**(1./3.)
C          RESET BURNED DEPTH OF GHOST GRAIN TO ZERO
        Y(IDEQBR+(K-1)*3+2)=0.0
C
        ICFLG(K)=1
        IGNC(K)=0
        THRC(K)=0.0
   10   CONTINUE
      RETURN
      END
```

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